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VOL. VII.

MARCH, 1928.

No. 1.

ON THE SHOOT MORPHOLOGY OF *LIMNANTHEMUM*.

BY J. F. R. d'ALMEIDA, B.A., B.Sc. (HONS).

St. Xavier's College, Bombay.

Goebel (3) was the first to elucidate the shoot morphology of *Limnanthemum*. He studied *L. indicum* and other species from this point of view. Besides this contribution and a general descriptive paper dealing with the development, branching, etc., of *L. nymphacoides* Hoffm. and Link by Wagner (5), there seems to be comparatively very little work done on this most interesting aquatic genus. Only a very inadequate notion of the morphological nature of the parts can be gained from the Floras, as the subtler details of morphology are not discussed therein.

The following account of the two Indian species, *L. cristatum* Griseb. and *L. indicum* Thwaites, by adding further details, emphasises the interpretations of the parts given by Goebel (3) and attempts to throw light on points of morphological interest which have either not been satisfactorily explained by previous writers or have escaped their attention.

L. cristatum.

The rhizome of *L. cristatum* (Figs. 1 and 2, Rh) is erect or slightly oblique. It bears a number of leaves (Fig. 2, L), petiole-like branches which we propose to call stolons (St) and roots (Rt). In some plants (Fig. 1) the part of the rhizome formed during the previous season (Rh1)—now marked with the scars (Sc) of old stolons and bearing some old roots (Rt1)—may still be found attached to the base of the portion of the rhizome (Rh) formed during the current season. The leaves that appear first on the rhizome are of the ordinary floating type characteristic of *Nymphaeas* consisting of orbicular, deeply cordate blades borne peltately on petioles which vary in length

with the depth of the water (Fig. 2, L). The petiole is slightly compressed at the base, where it bears a pair of thin membranous, adnate stipules (S). As we proceed upwards on the rhizome these floating leaves show a gradual transition to membranous scales. The latter are derived from the former by a process of reduction in which the petiole becomes flattened out and the blade dwindles down in size and changes in shape, becoming spatulate (L1), lanceolate, and finally disappearing altogether leaving the flattened petiole and midrib in the form of a subulate membranous scale-leaf (L2). These leaves Goebel (3) calls *Niederblätter* (under-leaves). The long-petioled floating leaves of the rhizome bear no branches in their axils but the scale-leaves which later on appear instead of them higher up the rhizome have each in their axil a branch, the stolon, very much resembling the petiole of the floating leaf described above except for the absence of stipules. Each stolon bears at the surface of the water a short-petioled floating leaf (Figs. 1, 2 and 3, L3) and an inflorescence (Figs. 1, 2, and 3, If). Between these two is an abbreviated stem (Figs. 2 and 3 AS) which arises as a bud (vegetativer Spross.) This abbreviated stem resembles the parent rhizome and repeats the production of stolons (Fig. 3, St1) in the axils of scale-leaves (L4). From the abbreviated stem may hang down into the water a few stout roots (R) of a green colour which are usually branched. Each stolon borne on the abbreviated stem in turn bears a short-petioled floating leaf, an inflorescence, and an abbreviated stem like the parent-stolon and in this way the branching may go on indefinitely (Fig. 3).

It was at first supposed that the long stalk given off from the rhizome (which we have here called stolon), since it bore both lamina and flowers, was a petiole, and that the flowers were borne laterally from it. Such a view was entertained by Grisebach (4), Eichler (2) and others. Goebel (3) has shown this interpretation of the parts to be erroneous, that the leaf though occupying a terminal position is in reality a lateral organ, whilst the inflorescence is terminal and that in the course of development the leaf has pushed the growing point to one side and comes to occupy a terminal position. This being the case, the abbreviated stem which grows out of a bud between the leaf and the inflorescence is really an axillary branch and the branching of the plant is to be looked upon as a mixed cyme. The petiole (p) of the floating leaf which is only about 5-3 cm. long has a sheathing base which together with its stipular appendages envelopes and protects the inflorescence when young and persists as a collar round its base after it has expanded. This collar is very conspicuous in *L. indicum* (Figs. 5 and 6 Sh). The inflorescence is not cymose as

has been described in the case of *L. nymphaeoides* by Wagner (5) and in the case of other species by Goebel (3). Neither in *L. cristatum* nor in *L. indicum* is there a terminal flower. The inflorescence in both these plants is of the racemose type and may be described as a corymb with a very short main axis. The individual flowers spring from the axils of small membranous scale-like bracts (Figs. 3 and 6 Br). They are borne on long pedicels and expand one at a time in acropetal succession.

L. indicum.

L. indicum is a much larger plant, with larger leaves (up to 30 cm. or more in diameter) and stouter stolons. The rhizome is much thicker and the stolons spring in the axils of membranous scales as do those of *L. cristatum*. The roots borne by the abbreviated stems are not, however, green like those of the latter plant.

From the specimens examined the writer is unable to say whether there are any long-petioled floating leaves in *L. indicum* like those which first appear on the rhizome of *L. cristatum*. Goebel (3) has suspected the existence of such leaves in younger plants which he has not had the opportunity to investigate. The presumption, on the whole, seems to be in favour of their occurrence in younger plants, and this presumption is confirmed by the fact that the abbreviated stem (borne on the stolon) which is to be looked upon as the morphological equivalent of the rhizome has in addition to the ordinary subulate scale-leaves (L1) one or more scale-leaves (Figs. 5 and 6 L2) which possess a type of floating lamina (f) which is clearly an approach to the peltate floating lamina borne on a long petiole.

Goebel (3) considers that the peculiar habit of the plant, in having both the flowers and the foliage leaf on one and the same stalk, confers a definite biological advantage. In the first place the broad swimming leaf lying on the surface of the water gives the inflorescence the requisite support and enables it to raise its flowers well above the water-surface so as to attract insects. In addition to this the stolon forms a substitute for both the elongated petiole and peduncle of the water-lilies, so that the materials assimilated in the floating leaf-blade find their way by the shortest route to the ripening fruit instead of, as in *Nymphaea*, having to descend to the rhizome down the petiole and then to ascend again a similar distance up the peduncle. "But," as Goebel suggests, "such an arrangement as met with in *Limnanthemum* would have less value in the case of water-lilies, because the *Nymphaeaceae* store so much food in their rhizome that the ripening of the fruit is not dependent upon the

products of contemporaneous assimilation" (3). According to Arber (1) it would be "utterly unsafe to suppose that the morphological differences between the water-lilies and *Limnanthemum* are to be explained on such simple adaptational lines, though it is obvious, from the success which both families achieve that their respective types of construction must be well suited to aquatic life." To the present writer's mind the totally different structure of these two genera of water plants is to be attributed to their having sprung from phylogenetically distinct stocks whose original construction was so different from each other that, when they took to the water, each evolved along the lines laid down in its original structure and produced types which, though differing widely from each other, were equally suited to live in water, in other words to achieve the same object, in two different ways.

We have seen above that the floating leaves first borne by the rhizome have no stolons in their axils, but that the upper scale-leaves bear each in their axils a stolon from which springs laterally a large floating leaf. It appears that the occurrence of the latter renders the possession of laminae by the radical leaves which subtend the stolons superfluous. These leaves consequently undergo reduction to mere scales.

The most conspicuous feature of the two species of *Limnanthemum* just described is the repeated branching by means of vegetative buds which become abbreviated stems as seen in Figs. 3 and 5. This branching is carried on on all sides without stint. Thereby the plant is able to explore the surrounding expanse of water so as to cover the surface with a close mosaic of leaves which not only secures for the plant the best illumination but also effectually checks the growth of competitors. The development of adventitious roots in connection with each abbreviated stem provides an efficient means of vegetative multiplication, since by means of these roots each abbreviated stem is clearly able to feed itself and live an independent life in case it should become separated off from the rest of the plant (e.g. by the decay or breaking up of the connecting shoot or stolon). In this connection it may be mentioned that *Limnanthemum* is very tenacious of life. Pieces of the lamina of *L. cristatum* are capable of producing new plants (Fig. 4) and detached flowers of *L. indicum* may bear adventitious roots.

In conclusion it will not be out of place to observe that in *Limnanthemum* we have a type of water-plant which is intermediate in habit between the *Nymphaea* type which is rooted in the mud and the floating type whose roots do not penetrate the soil but hang freely in the water. The habit and mode of growth of *Limnanthemum*

suggest the lines along which floating plants have evolved from a type of plant originally rooted in the mud which like *Limnanthemum* were capable of producing, at the ends of branches that floated up to the surface of the water, plantlets which could live independently when detached.

Explanation of Figures.

Fig. 1. *Limnanthemum cristatum* Griseb. Plant with rhizome, stolons and roots. *Rh*, rhizome of the present season; *Rh1*, rhizome of the previous season; *St*, stolon; *Sc*, scars on the portion of the rhizome formed during the previous season; *Rt*, roots borne on the part of the rhizome of the present season; *Rt1*, roots of the portion of the rhizome of the previous season, *If*, inflorescence; *L3*, blade of the short-petioled leaf; *p*, petiole.

Fig. 2. A plant of *L. cristatum* Griseb. showing the transition from long-petioled floating leaves (*L*) to scale-leaves (*L2*) in the axils of which the stolons (*St*) arise. *S*, stipule of the long-petioled leaf; *Sh*, stipule of the short-petioled floating leaf (*L3*) forming a collar round the inflorescence (*If*); *P*, petiole of short-petioled floating leaf; *AS*, abbreviated stem which arises as an axillary bud between the inflorescence and the leaf.

Fig. 3. Upper portion of the shoot of *L. cristatum* Griseb. to show the branching. *St*, stolon borne on the rhizome; *If*, inflorescence; *br*, bract; *L3*, short-petioled floating leaf; *P*, its petiole; *L4*, scale leaves on the abbreviated stem (*AS*) in the axils of which stolons (*St1*) arise; *R*, roots borne on the abbreviated stem.

Fig. 4. Fragment of the leaf-blade of *L. cristatum* Griseb. which has produced a new plant. 1, 2, 3, 4 are the leaves in order of succession; *R*, roots.

Fig. 5. Upper portion of the shoot of *Limnanthemum indicum* Thwaites to show the branching. *St*, *St1*, *St2*, stolons borne respectively on the rhizome and the successive abbreviated stems; *L*, leaf-blade of the short-petioled leaf, *P*, its petiole; *If*, *If1*, *If2*; Inflorescences on the successive; stolons; *R*, roots coming off from the abbreviated stem; *L1*, Scale-leaf (subulate) on the abbreviated stem; *L2*, leaves on the abbreviated stem with floating laminae (*f*).

Fig. 6. Portion of the shoot of *L. indicum* Thwaites at the level of the inflorescence borne on the stolon springing from the rhizome. *St*, stolon; *If*, inflorescence; *Br*, bracts; *P*,

petiole of the short-petioled floating leaves; *Sh*, collar round the inflorescence formed by the sheathing base and stipular appendages of the short-petioled floating leaf. *R*, roots coming off from the base of the abbreviated stem; *L1* and *L2*, subulate scale-leaves and leaf with floating lamina (*f*) borne on the abbreviated stem; *St1*, stolon borne on the abbreviated stem.

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2. Eichler, A. W. (1875) Blütendiagramme I, p. 246.
3. Goebel, K. (1891) Morphologische und biologische Studien. VI *Limnanthemum* pp. 120-126. *Annales du Jardin Botanique de Buitenzorg*, Vol. IX.
4. Grisebach, A. H. R. (1845) In Decandolle Prodrum IX, p. 139.
5. Wagner, R. (1895) Die Morphologie des *Limnanthemum nymphaeoides* (L) Lk. *Bot. Zeit.* Jahrg. 53, Abt. I. pp. 183-205.

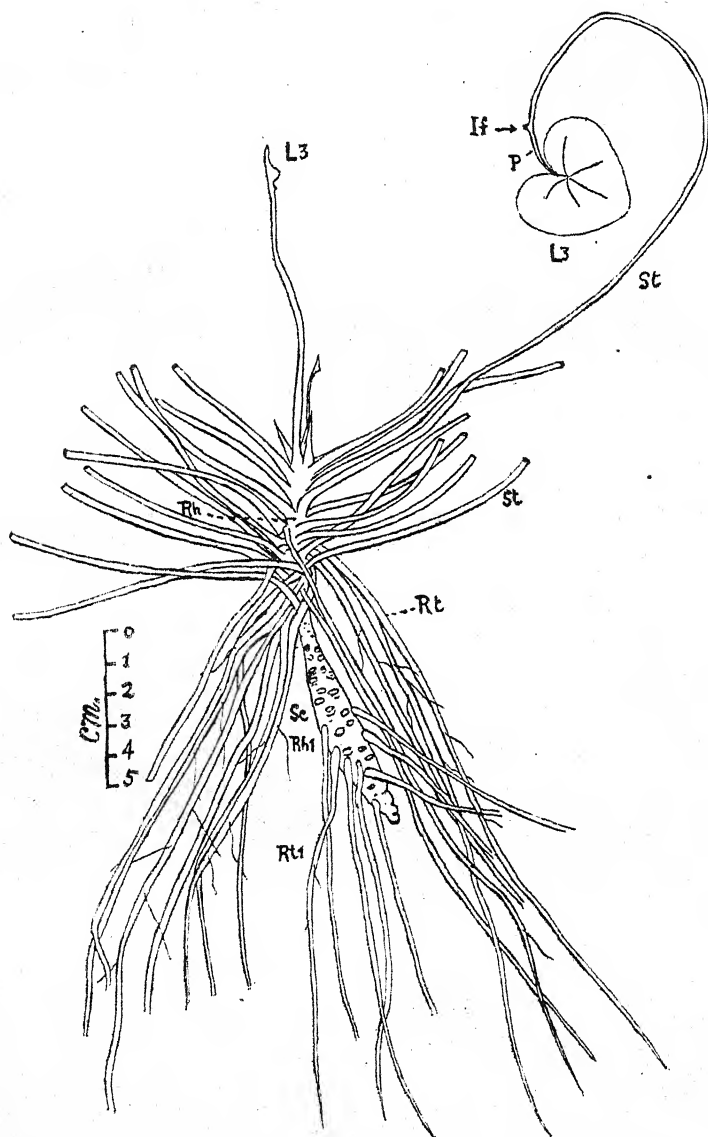


Fig. 1.

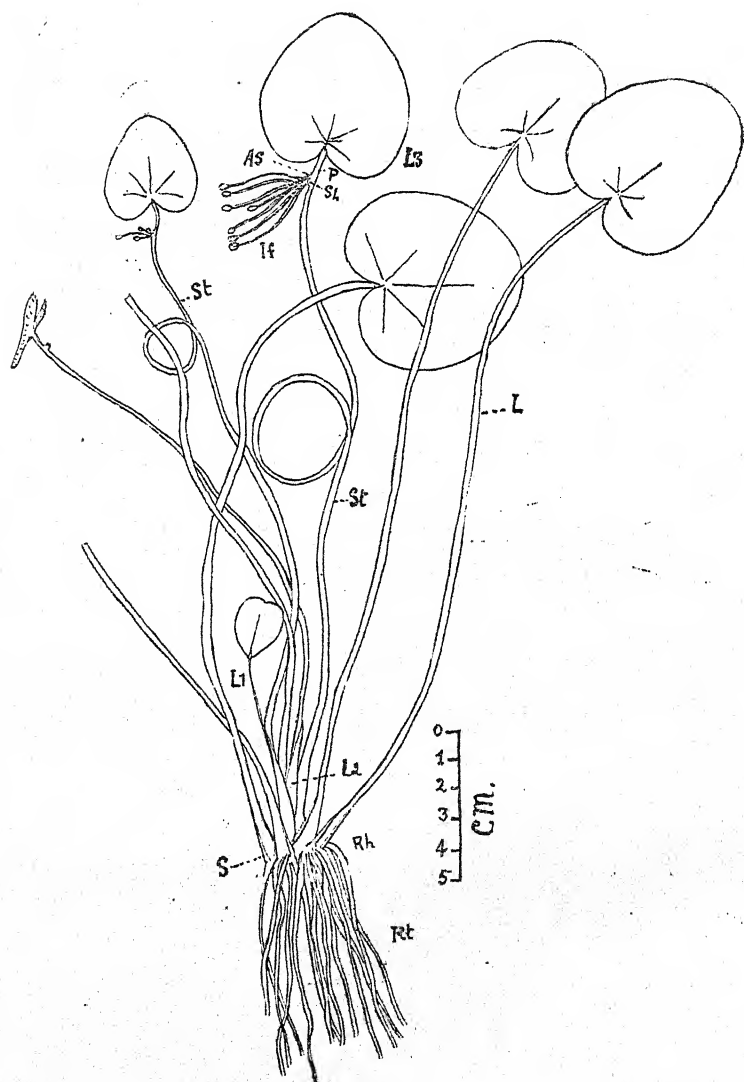


Fig. 2.

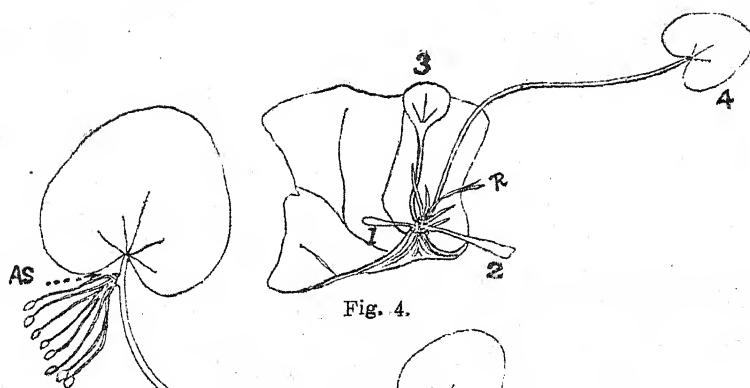


Fig. 4.

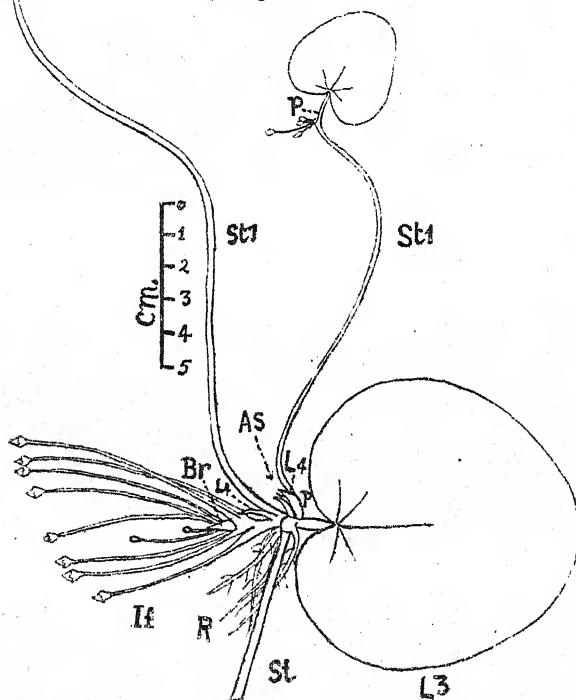


Fig. 3.

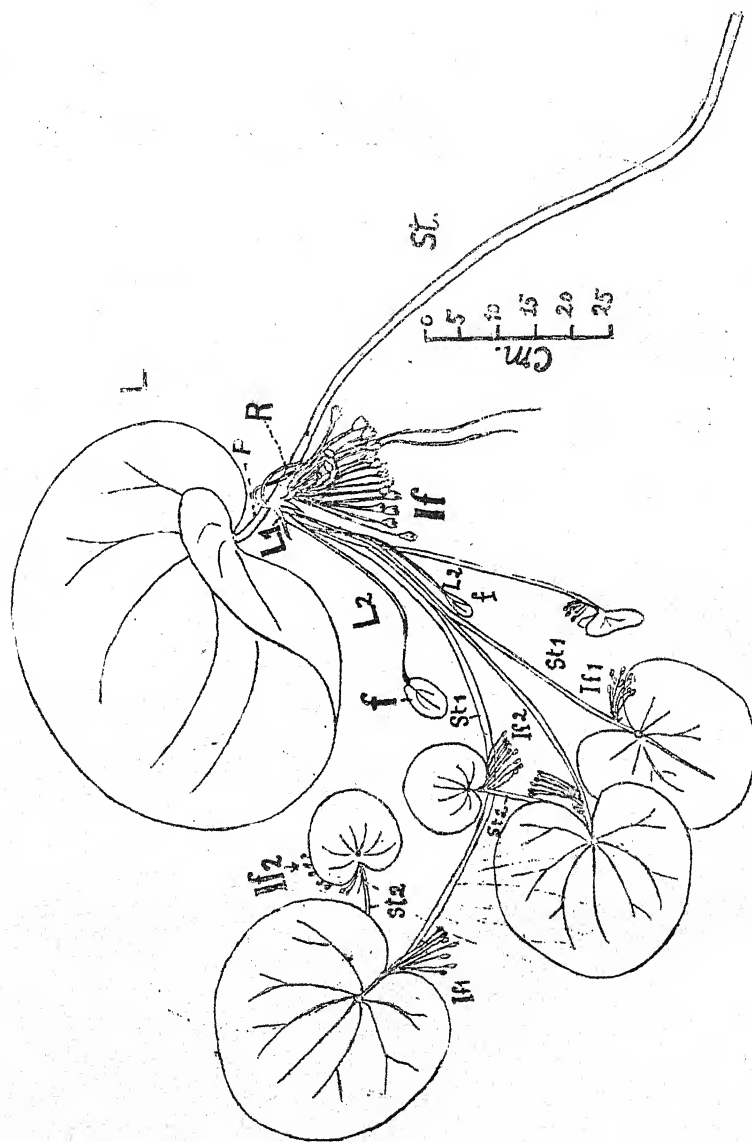


Fig. 5.

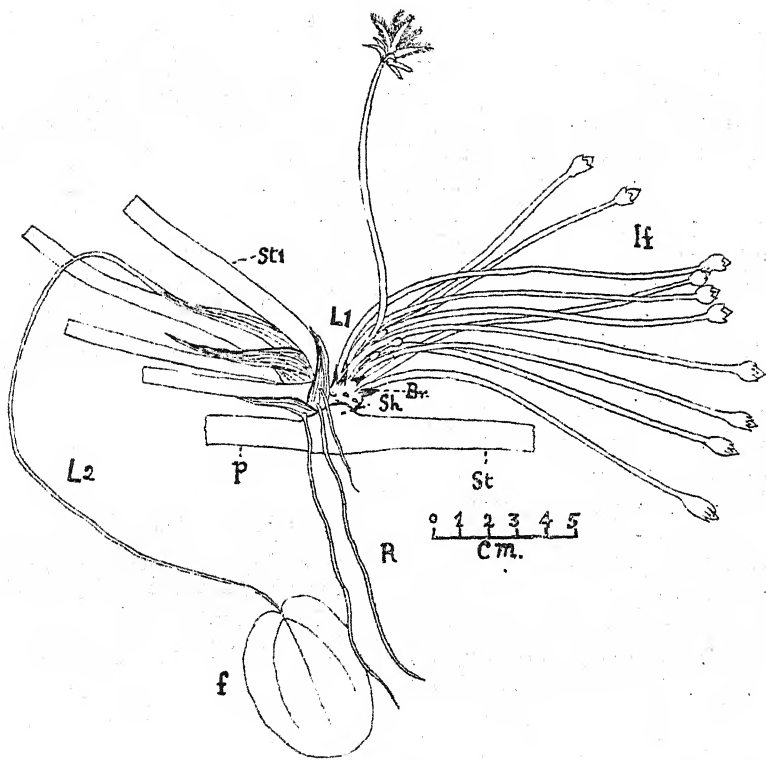


Fig. 6.

THE ORIGINAL HOME OF *SANTALUM ALBUM* LINN.

By C. E. C. FISCHER.

In Kew Bulletin 1927 p. 193 Messrs. T. A. Sprague and V. S. Summerhayes have discussed the distribution of certain genera of the *Santalaceae* in Malaysia and Polynesia and have 're-established the genera *Eucarya* and *Mida*. A diagram (p. 199) shows the peculiar distribution of the genus *Santalum* which, with the exception of a small overlap with *Eucarya* in the south-east of Australia, occupies a quite distinct habitat from that of the other two genera. The area occupied by *Santalum*, with about 15 described species, (excluding those now attributed to *Eucarya* and *Mida*), lies in North and South-East Australia, New Guinea and a number of the Pacific Islands as far north as the Hawaiian Isles. One species only, *Santalum album* Linn., occurs right outside this general habitat, being found only in Southern India and in a group of Malayan islands including the eastern part of Java and some others centering round Timor. It would seem, therefore, that the focus of the genus *Santalum* must be somewhere in the west central portion of the Pacific Islands (especially considering that the Hawaiian Isles are the richest in genera, about 10), and that *Santalum album* is a western outlier.

But the spread of *Santalum album* itself is also extraordinary since it is found in a limited area of South India and also in a limited tract of the Malay Archipelago and nowhere else, the two localities being separated by a distance of about 2500 miles.

At the date it is impossible to give a reply to the question: "What is the actual area in Southern India in which *Santalum album* is indigenous?"; it would be best answered by the further question: "Is *Santalum album* really indigenous in India?"

When Buchanan-Hamilton made his tour through Mysore, Kanara, Malabar and Coimbatore in 1800 he found sandal restricted to a very much smaller area than it now occupies, *viz.*, mainly in the eastern and drier part of Mysore with an outlier in western Salem and hardly any in western Mysore or Coorg. Now its limits have been very greatly extended, especially in the present century by artificial as well as natural (birds) means.

These facts led to the further investigation of the problem when it was ascertained that in the middle of the XVIth. century according to the authors Garcia and Acosta, practically all, if not indeed all, the sandalwood exported from Calicut both inland and outwards

had been first brought by sea from Timor and the adjoining islands by Chinese merchants of whom there was a colony in that neighbourhood. Now if *Santalum album* is truly indigenous in India how are these facts to be accounted for? They are very simply explained if one assumes that the species is not really indigenous in India but was introduced from Timor at some time in the XVth century or earlier and that after a preliminary period of acclimatisation it thrived in a way comparable to *Lantana Camara* Linn. or *Opuntia Dillenii* DC., both of which are now pests in the same or adjoining tracts to those occupied by sandal. From the commercial standpoint the situation would be parallel to that of *Hevea brasiliensis* Muell.-Arg, the Para rubber.

It would be of very great interest if readers of this journal were to bring forward some definite information from authentic sources, either in support or disproof of this hypothesis. I would, however, point out that evidence of usage of sandalwood in remote epochs in India is of no material value since that is not disputed; indeed, we know that 2000 years before the XVIth century sandalwood was known in Palestine where no one presumes it to have ever been grown. What is required is indisputable evidence that sandal grew indigenously in India before that period and at a date prior to the trading by Chinese adventurers along the coasts of India. In this connexion it must be noted that in the old days (certainly up to the XVIth. century) there was considerable confusion between the white and yellow sandalwoods (true *Santalum*) on the one hand and red sandalwood (Redsanders, *Pterocarpus santalinus* Linn f.) on the other.

Any one desiring further particulars is advised to read the article in the Kew Bulletin referred to at the head of this note.

THE HERBARIUM KEW,
9th. November, 1927.

**A NEW SPECIES OF PETALOPHYLLUM,
PETALOPHYLLUM INDICUM KASHYAP.***

BY SHIV RAM KASHYAP,
Government College, Lahore.

Two species of the genus *Petalophyllum* have been described by Stephani in his *Species Hepaticarum*. None has so far been found in India. The present note describes a new species found on the bank of the river Ravi in Lahore.

Plants simple or furcate, growing singly or in patches of 3 or 4, up to 12 mm. long and 7 mm. broad. Basal portion cylindrical and wingless. Wing many-layered at the base, gradually becoming one-layered, wavy along the margin. Lamellae one cell thick and 15 to 24 cells high, running outwards and forwards, not always parallel. Dioecious. Antheridia in groups behind the apex, protected by scattered scales. Archegonia in groups of 4-7 on the midrib, protected by a bell-shaped perianth with a lacerated margin, often with 2 or 3 splits along the whole length. Sporogonia 1-4, usually one in each perianth. Pedicel usually 10 to 20 mm. long sometimes very short, occasionally up to 25 mm. Capsule 2 mm. in diameter, spherical, dark brown. Capsule wall usually 3-layered; cells of outer layer thin-walled, with thick radial walls sometimes; those of the inner layers with thick annular or sometimes semi-annular bands. Spores dark brown, about 40μ in diameter, spherical with a membranous wavy margin, reticulate-lamellate, 3-4 reticulations in the diameter; reticulations pentagonal or hexagonal, $8-10\mu$, marginal wing 14 to 17μ . Elaters trispiral, lightly coloured except the spiral bands which are very distinct brown and lax, $280-400\mu$ long, $8-10\mu$ broad, simple or occasionally branched, attenuated towards both ends. A few elaters are short and broad, about 16μ broad.

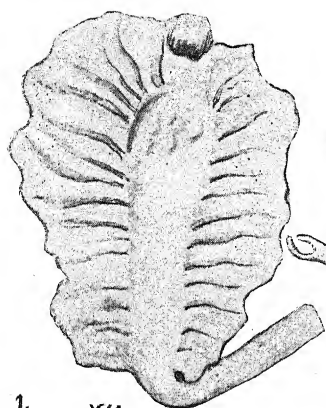
At the end of the season the apex becomes thickened, forming a tuber, and becomes buried underground.

Found by Pt. Bhagat Ram Vasisht, M. Sc., for the first time in November 1925, on the banks of the river Ravi at Lahore. The plant grows in winter.

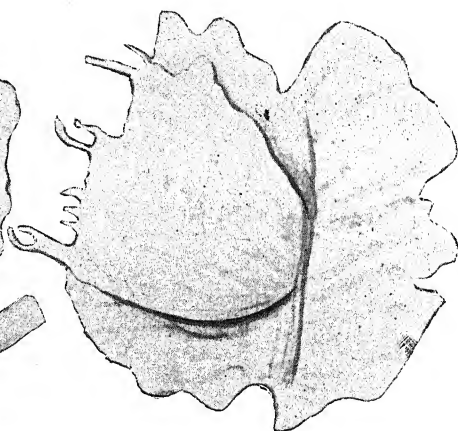
Explanation of figures 1-5

1. A male plant with a few antheridia. Note the apical tuber.
2. A female plant with the perianth.
3. A perianth with a ripe sporogonium.
4. Two spores.
5. An elater.

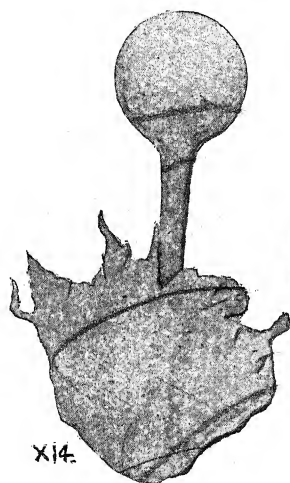
* Read before the Botany Section of the Indian Science Congress Calcutta, January, 1928.



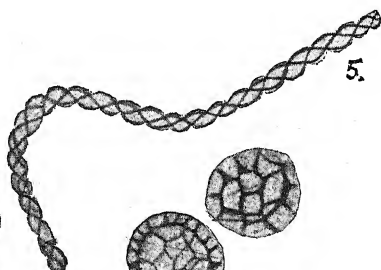
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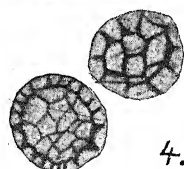
X14. 2.



3. X14.

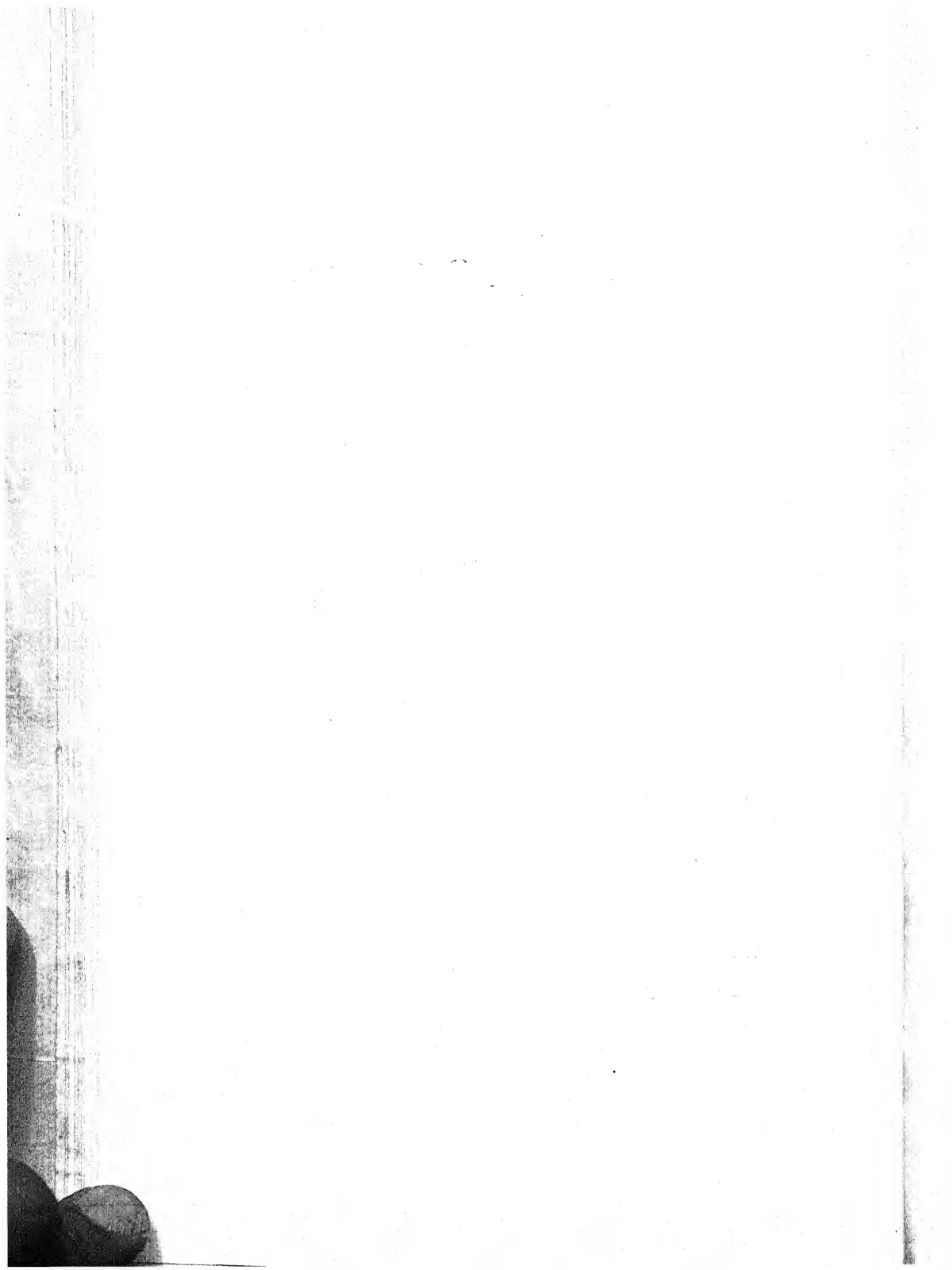


5.



4. X480.

Kashyap: Petalophyllum.



AKINETES IN A SPECIES OF *OEDOGONIUM*.

BY

M. R. HANDA, M. SC,

University College, Rangoon.

During October 1927 the writer collected algae in Taunggyi (4675 ft. above sea-level) and other places in the Southern Shan States of Burma. An account of the algae from the above-mentioned stations will be published later. Here reference will only be made to an unusual occurrence—the presence of akinetes or resting spores in a species of *Oedogonium*. The occurrence of such resting spores in this genus, so far as the writer is aware, has only been recorded by Wille in a paper¹ unfortunately not accessible in Rangoon.

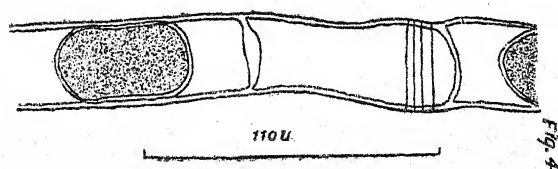
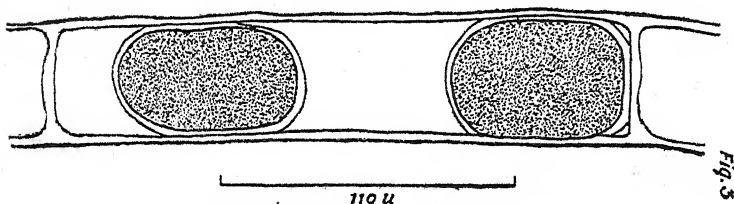
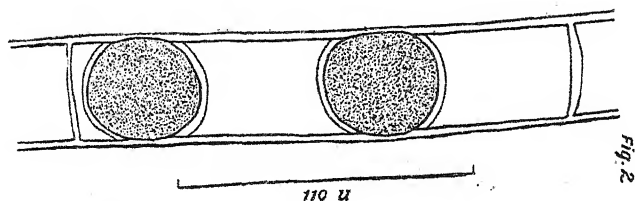
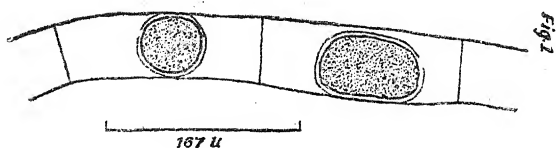
The filaments under examination, though devoid of sexual organs, can be referred to the genus *Oedogonium* by virtue of the possession of the characteristic "cap-cells." The plants were growing intermingled with other algal associates in a shallow body of water replenished occasionally by the drainage from adjacent higher land. The number of akinetes present in a cell varied from one to two (Figs. 1–3). In shape, they were either roundish (Fig. 2) or broadly ellipsoidal (Fig. 3), and possessed a double coat.¹

The vegetative cells were 35–41 μ thick, 77–200 μ long; akinetes 27–41 μ thick, 41–66 μ long but, when roundish, 39–41 μ in diameter.

In the present state of our knowledge, the factors governing the formation of resting spores in the genus *Oedogonium* cannot be stated with any exactitude. From the nature of the case under consideration, it is probable that a high altitude with its accompanying low temperature may influence their production. Further observations are needed on this and other factors.

In conclusion I offer my thanks to Dr. S. L. Ghose for his help and suggestions. I have also much pleasure in acknowledging my indebtedness to the University of Rangoon for financial assistance.

¹ Bot. Centralbl. XV1, 1883, p. 217: quoted by West and Fritsch (1927): A Treatise on the British Freshwater Algae. Cambridge.



Explanation of Figures 1—4.

- Fig. 1. Portion of thallus of *Oedogonium* sp. showing akinetes occurring singly.
 Fig. 2. Two rounded akinetes in a cell.
 Fig. 3. Two broadly-elliptical akinetes in a cell.
 Fig. 4. Showing both akinetes and cap-cells.

RANGOON,
 2nd January, 1928.

STUDIES IN GROWTH, SENESCENCE AND REJUVENESCENCE IN PLANTS

1. A COMPARATIVE STUDY OF THE RESPIRATORY INDEX, WATER-CONTENT AND THE RATE OF HEALING OF MECHANICAL WOUNDS IN

HIBISCUS ESCULENTUS

BY BHOLA NATH SINGH, D.Sc.,

Assistant Professor of Plant Physiology, Benares Hindu University.

[With one figure in the text.]

In the course of some work on the respiration of the meristematic tissues of crop plants, it was noticed by the author while working as a student under Professor Inamdar that the values of respiration began to fall down sooner or later with the age of the plant¹. If respiration of this tissue can be considered an index of the general activity of the protoplasm in the plant at different stages of its growth, it was thought a matter of great interest to observe if other physiological processes such as the power of healing of mechanical wounds by the formation of callus are also similarly affected with the growth stages of the plant. The results obtained in this connection seem to throw interesting light on the phenomenon of growth and senescence in plants.

The researches of Massart² and Simon³ have already shown that the power of formation of callus in the wounded region disappears early in some cases and late in others, the disappearance being particularly rapid in the cells of the root cortex. From the available literature it appears that no observations have yet been recorded where the rate of callus formation has been studied in the corresponding regions of the plant at different stages of its life-history.

The following observations were made on *Hibiscus esculentus* germinated on the same date and grown under field conditions. Wounding was effected by carefully removing, as far as possible, the epidermal layer of the stem at two places on the stem, one just below the apical growing region and the other in the middle of the stem length, in order to get a comparison of the variations in the relative time of healing (callus formation) in the stem portions of different age and developmental stage. This procedure was repeated at intervals

¹ Singh, B.N., 'D.Sc. thesis' Benares Hindu University. 1927 (Detailed results to be described elsewhere subsequently). See also Kidd, West and Briggs 'Proc. Roy. Soc.' B. Vol. xcii, 1921 and cf. Inamdar, Singh, and Pande, 'Ann. Bot.', Vol. xxxix, 1925.

² Massart, 'Mémoires Acad. Bruxelles', 57, 1898 (See Jost's Plant Physiology, Eng. Ed. 1907).

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throughout the ontogeny of the plants. The time taken for the healing of the wound by the formation of callus was thus carefully noted in each case at two regions on the stem during successive stages of growth.

A reference to the following table will indicate in the first instance that the rate of cicatrization goes on decreasing in each case with the comparative age of the stem from the apical growing region downwards. But a special point of interest attaches to the results obtained on the activity of the cells near the *apical growing region* at different stages of the growth of the plant. These results indicate that the rate of healing near the apical meristem remains practically constant up to the forty-fifth day after germination, after which there is a steady decrease in the rate as can be noticed by a gradual increase in the time taken for the completion of callus formation, the rate varying in inverse ratio to the age of the plant.

Age of plants in days.	Respiratory index of the meristematic tissue, CO ₂ output per gram dry weight at 15°C.	Percen- tage moisture- content.	Relative rate of callus formation in the wounded region in days		Remarks.
			Apical growing region.	Older stem.	
7	...	87.30	3	3	Stem very young.
10	8.31	87.31	4	7	
26	8.36	84.00	5	8	
45	7.30	82.22	4	16	
57	6.44	78.70	8	...	Initiation of re- productive organs.
75	6.45	71.54	11	...	
87	5.63	64.28	14	...	
107	4.11	66.89	...	...

N.B.—Seeds germinated on 24th April, 1925.

It is interesting to compare these results with the respiratory index of the apical meristematic tissue through successive stages of growth. The respiratory output of CO₂ per gram dry weight of this tissue taken at corresponding intervals of time at 15°C. on similar

plants are also included in the above table for comparison¹. It will be seen that the values of respiration go hand in hand with the relative rates of the power of healing at progressive stages of growth.

Kidd, West and Briggs² have particularly emphasised the importance of the respiration of the meristematic tissue as an index of the "internal" factor concerned in respiration and perhaps also of growth. It is interesting to obtain such a similarity of relations at successive stages of growth between respiration of this tissue on the one hand and such an important activity as the capacity for regenerating the power of cell division behind the growing region, on the other. There appears hardly a doubt that both of these are indications of a qualitative change in the protoplasm as growth proceeds towards senescence.

In view of these identical ontogenetic drifts in the two processes, one can hazard the statement that the gradual decrease in the relative growth rates of plants with the age of the plant as also the parallel course followed by the respiratory indices of plant organs throughout the life-cycle^{3, 4, 5, 6} are partly at any rate due to this internal factor of senescence in the protoplasm. What this protoplasmic senescence is actually due to is a problem for further work.

One of the factors at any rate concerned in the process of senescence appears to be moisture-content. An analysis of the water-content of this growing region was also simultaneously made at corresponding stages of the growth of the plant. The figures are of special value in that they indicate a parallel course of the moisture-content curve with the two metabolic activities of the cell mentioned above, *viz.*, respiration and the power of cicatrization of superficial wounds. The relations of the three in the growing apical region with advance in the growth stages of the plant are made out more clearly in the following figure where the rate of healing is expressed in terms of the reciprocals of the number of days taken for the formation of callus.

¹ For methods see Inamdar, R.S. and Singh, B.N., 'Studies in the respiration of tropical plants.' Journ. Ind. Bot. Soc., Vol. VI. Nos. 3 and 4, pp. 133-212, 1927.

² Kidd, West and Briggs. *loc. cit.*

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⁴ Singh, B. N., 'The Growth of the Cotton Plant in India' in several parts, D. Sc. thesis, Benares Hindu University, 1927.

⁵ Singh, B. N. and Apte., Experimental Researches on Growth of Tropical Plants, Pt. I, A Comparative Study of the Growth Rates and Respiration throughout the life-cycle of the Radish Plant during successive periods of growth in relation to leaf-area and leaf-weight ratios. Proc. 14th. Ind. Sci. Congress 1927.

⁶ Singh, B. N. and Apte, V. V., Pt. II., 'Seasonal Variations in the growth rate and respiration in relation to leaf-area and leaf-weight ratios' Proc. 14th. Ind. Sci. Congress 1927.

The closeness of connection in the respiratory activity and the rate of callus formation which is an expression of the power of regenerating cell multiplication is remarkable. Perhaps the course of either of them should give a measure of the gradient of the protoplasmic senility in the plant as growth proceeds. It is further interesting that the two activities are correlated with the relative moisture-content of the tissue examined.

It is by no means intended to convey the idea that the phenomenon of senescence is connected entirely with the moisture-content of the tissues. What this note intends to emphasise at this stage is that the correlated run of many physiological activities as growth proceeds, such as the power of regenerating, cell multiplication, respiration, assimilation,¹ growth, etc. appear to be the general expression of a "metabolic senescence" of the protoplasm itself which seems to affect many physiological activities simultaneously inspite of their diversities. Of the possible many factors which induce this senescence, by no means an insignificant part is played by the relative moisture-content of the growing tissue as growth proceeds.

Summary and Conclusion

(1) A comparative study is made of the simultaneous rates of respiration, power of callus formation in the wounded area and moisture-content in or very near the growing apical region of *Hibiscus esculentus*.

(2) It is observed that all the three phenomena noted exhibit a parallel course as growth proceeds, showing a progressive decline particularly during the later stages of growth, the rates varying in inverse ratio to the age of the plant.

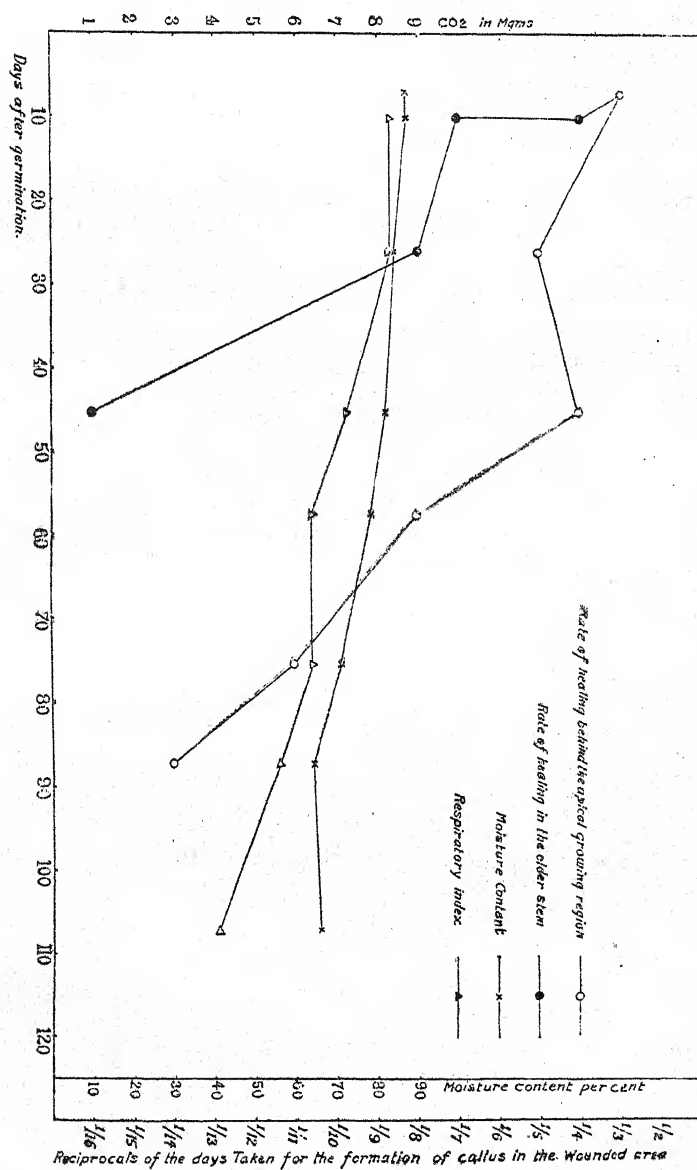
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(4) It is shown that moisture-content is one of the important factors which induces this qualitative change in the protoplasm.

In conclusion the author is very much indebted to Professor R.S. Inamdar for his continued interest and inspiration, and for his valuable suggestions and kind criticisms.

DEPARTMENT OF BOTANY,
BENARES HINDU UNIVERSITY.

¹ Singh, B. N. and Kumar, K., 'Ontogenetic Drifts in the Photosynthetic Activity of the Foliage Leaves of the Radish Plant,' Proc. 14th. Ind. Sci. Congress 1927, where a decline has been observed in the rate of assimilation in the case of very young leaves as growth proceeded.



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W

A COMPARATIVE STUDY OF THE RESPIRATORY INDEX, WATER-CONTENT AND THE RATE OF MECHANICAL WOUNDS IN *HIBISCUS*

ESCULENTUS

BY BHOLA NATH SINGH, D.Sc.,

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[With one figure in the text.]

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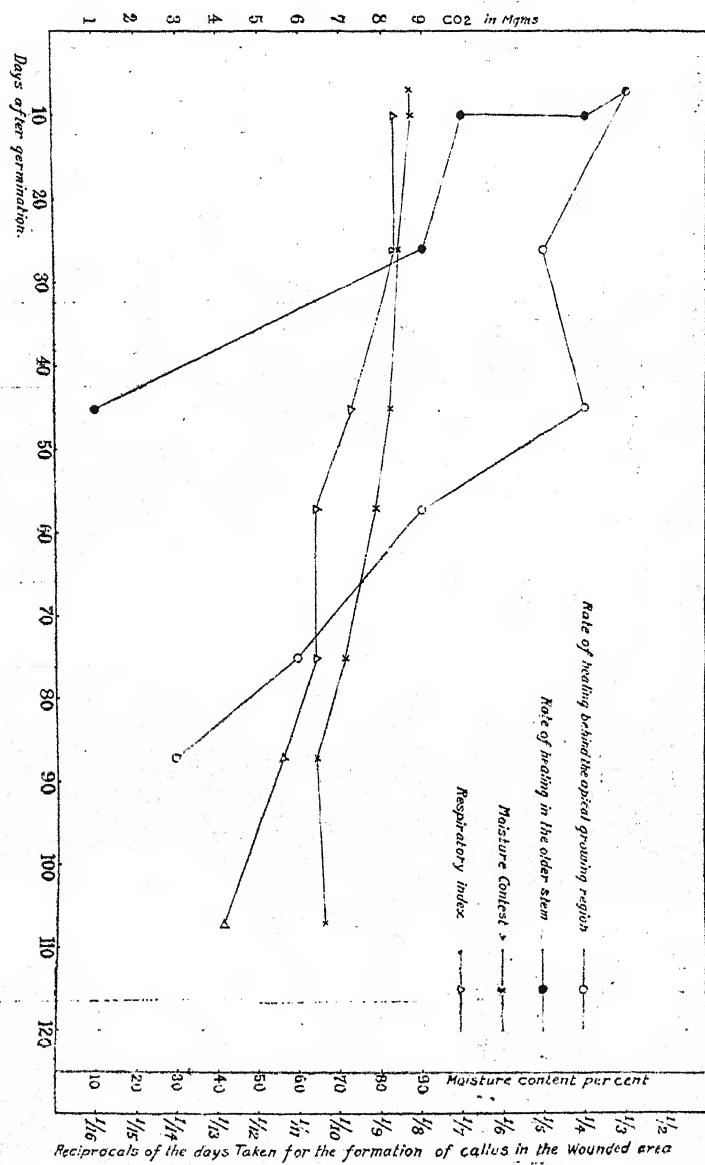
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(Reference contd. from page 4) the life-cycle of the Radish Plant during successive periods of growth in relation to leaf-area and leaf weight ratios', Proc. 14th. Ind. Sci. Congress 1927.

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COMPARATIVE STUDY OF THE RESPIRATORY INDEX. 21



THE FLORA OF THE INDUS DELTA.

By E. BLATTER, S.J., Ph.D., F.L.S., C. McCANN, Assistant Curator, Bombay Nat. Hist. Society
AND T. S. SABNIS, B.A., M.Sc., Economic Botanist to the Government, U.P.

(Continued from p. 132 Vol. VI, Nos. 3 and 4.)

PART IV.—B. PLANT-GEOGRAPHICAL CONSIDERATIONS.

I. Statistical Notes.

The following table gives a conspectus of the indigenous and introduced species and genera of the Indus Delta, and the same data for the Sundribuns. We add the latter in this place in order to save space, though we shall discuss the floristic relations between the two deltas later on.

FAMILIES.	INDUS DELTA.						SUNDRIBUNS.					
	Genera			Species			Genera			Species		
	Indi- genous	Intro- duced	Total	Indi- genous	Intro- duced	Total	Indi- genous	Intro- duced	Total	Indi- genous	Intro- duced	Total
Ranunculaceæ	...	...	...	...	...	...	1	...	1	1	...	1
Menispermaceæ	1	...	1	1	...	1	1	...	1	1	...	1
Nymphæaceæ	2	...	2	3	...	3	...	...	...	...	...	...
Cruciferae	1	2	3	1	3	4	1	...	1	1	...	1
Capparidaceæ	5	...	5	6	...	6	3	1	4	3	1	4

[illegible]

FAMILIES.	INDUS DELTA.						SUNDRIBUNS.					
	Genera			Species			Genera			Species		
	Indi- genous		Intro- duced	Indi- genous		Intro- duced	Indi- genous		Intro- duced	Indi- genous		Intro- duced
	
Olacaceæ	1	...	1	...	1	...
Celastraceæ	...	1	...	1	1	1	1	...	1	...	1	...
Rhamnaceæ	...	1	...	1	1	2	1	...	1	1	1	...
Ampelidaceæ	2	...	4	...	2	...
Sapindaceæ	3	...	3	...	3	...
Anacardiaceæ	...	1	...	...	1	1	2	...	2	...	2	...
Moringaceæ	...	1	...	...	1	1	...	...	...	...	...	...
Leguminosæ.	...	13	9	23	12	35	21	4	32	6	25	...
Droseraceæ	1	...	1	...	1	...
Rhizophoraceæ	...	3	...	5	...	5	4	...	6	...	4	...
Combretaceæ	2	...	2	2	1	...	1	...	1	...

Myrtaceae	...	...	1	...	1	1	1	3	1	3	4
Lythraceae	...	2	2	2	4	4	2	2	...	2	3
Papayaceae	...	...	1	...	1	1	...	...	...	...	...
Turneraceae	...	...	...	...	...	...	1	1	...	1	1
Passifloraceae	...	...	...	...	...	...	1	1	...	1	1
Cucurbitaceae	...	7	...	7	7	7	6	7	...	6	7
Ficoidaceae	...	3	...	4	3	4	2	2	...	2	2
Rubiaceae	...	...	...	...	...	...	5	6	...	5	6
Compositae	...	14	...	18	14	18	11	12	...	11	12
Goodeniaceae	...	1	...	2	1	2	...	...	...	...	...
Plumbaginaceae	...	1	...	1	1	1	1	1	...	1	1
Myrsinaceae	...	1	...	1	1	1	1	1	...	1	1
Ebenaceae	...	...	...	...	...	...	1	2	...	1	2
Oleaceae	...	...	1	...	1	1	...	...	...	...	...
Salvadoraceae	...	1	...	2	1	2	1	1	...	1	1

FAMILIES.	INDUS DELTA.						SUNDRIBUNS.					
	Genera			Species			Genera			Species		
	Indi- genous			Intro- duced			Indi- genous			Intro- duced		
	Indi- genous	Intro- duced	Species	Indi- genous	Intro- duced	Species	Indi- genous	Intro- duced	Species	Indi- genous	Intro- duced	Species
Apocynaceae	1	1	1	1	1	2	2	...	2	...	...	2
Asclepiadaceae	7	1	8	1	1	8	9	...	11	12	...	12
Gentianaceae	1	...	1	...	...	1	1	...	2	2	...	2
Hydrophyllaceae	...	...	...	...	...	...	...	...	1	1	...	1
Boraginaceae	3	...	9	...	...	3	9	...	3	3	...	3
Convolvulaceae	5	...	13	1	1	5	14	...	4	9	...	9
Solanaceae	5	2	7	3	3	7	10	...	1	4	...	4
Scrophulariaceae	6	...	7	...	...	6	7	...	5	5	...	5
Orobanchaceae	1	...	1	...	...	1	1	...	...	...	...	...
Lentibulariaceae	...	...	...	...	...	...	...	...	1	2	...	2
Bignoniaceae	1	...	1	...	...	1	1	...	1	1	...	1

Pedaliaceae	...	...	1	...	1	1	1	1	...	1	...	...
Acanthaceae	...	4	1	7	1	5	8	3	...	6	...	3
Verbenaceae	...	3	...	3	...	3	3	6	...	12	...	6
Labiatae	...	3	...	4	1	3	5	3	...	4	...	3
Nyctaginaceae	...	1	...	2	...	1	2	...	...	...	...	...
Amarantaceae	...	8	...	11	...	8	11	3	...	3	2	3
Chenopodiaceae	...	6	...	8	...	6	8	4	...	4	...	4
Polygonaceae	...	1	...	1	...	1	1	...	...	...	...	...
Aristolochiaceae	...	1	...	1	...	1	1	1	...	1	...	1
Lauraceae	...	...	...	...	...	...	...	1	...	1	...	1
Loranthaceae	...	...	...	...	...	...	...	2	...	4	...	2
Euphorbiaceae	...	3	1	11	4	4	15	14	...	16	...	14
Moraceae	...	...	1	...	1	1	1	...	...	...	...	...
Urticaceae	...	1	...	1	2	1	3	3	...	6	...	3
Casuarinaceae	...	...	1	...	1	1	1	1	...	1	...	1

FAMILIES.	INDUS DELTA.					SUNDRIBUNS.				
	Genera		Species		Total	Genera		Species		Total
	Indi- genous	Intro- duced	Indi- genous	Intro- duced	Genera	Indi- genous	Intro- duced	Indi- genous	Intro- duced	Species
Salicaceae	1	...	1	...	1	...	...	...	...	...
Ceratophyllaceae	...	...	...	...	...	1	...	1	...	1
Gnetaceae	1	...	1	...	1	...	...	...	...	...
Hydrocharitaceae	1	...	1	...	1	4	...	4	...	4
Orchidaceae	...	...	...	...	...	8	...	13	...	13
Scitamineae	...	1	...	1	1	2	...	2	...	2
Amaryllidaceae	1	...	1	...	1	1	...	1	...	1
Dioscoreaceae	...	...	...	...	...	1	...	1	...	1
Liliaceae	1	...	3	...	1	1	...	1	...	1
Commelinaceae	1	...	1	...	1	2	...	2	...	2
Flagellariaceae	...	...	...	...	...	1	...	1	...	1

Palmae	...	1	1	1	2	2	4	2	2	4	2	6	6	2
Pandanaaceae	...	1	1	...	1	1	1	...	...	2	...	1	1	2
Typhaceae	...	1	2	...	1	2	1	1	...	2	...	1	1	2
Araceae	...	...	...	...	...	...	2	...	...	2	...	2	2	2
Lemnaceae	...	1	1	...	1	1	...	...	...	...	...	...	...	...
Alismaceae	...	1	1	...	1	1	...	...	...	...	...	...	...	...
Naiadaceae	...	3	4	...	3	4	2	2	...	2	...	2	2	2
Cyperaceae	...	4	11	...	4	11	9	19	...	19	...	9	9	19
Gramineae	...	28	40	6	30	46	22	29	...	29	...	22	22	29
TOTAL	...	184	279	53	220	332	229	304	13	237	13	237	237	317

The species observed in the Delta, including the introduced plants, number 332, belonging to 220 genera and 73 families. Of these are indigenous 61 families, 184 genera, and 279 species. From now we shall confine ourselves to the indigenous plants only.

The ratio of families to genera and species is 1 : 3.01 : 4.57, or approximately 1 : 3 : 4.5.

A comparison of the Dicotyledons with the Monocotyledons shows the great poverty of the latter :

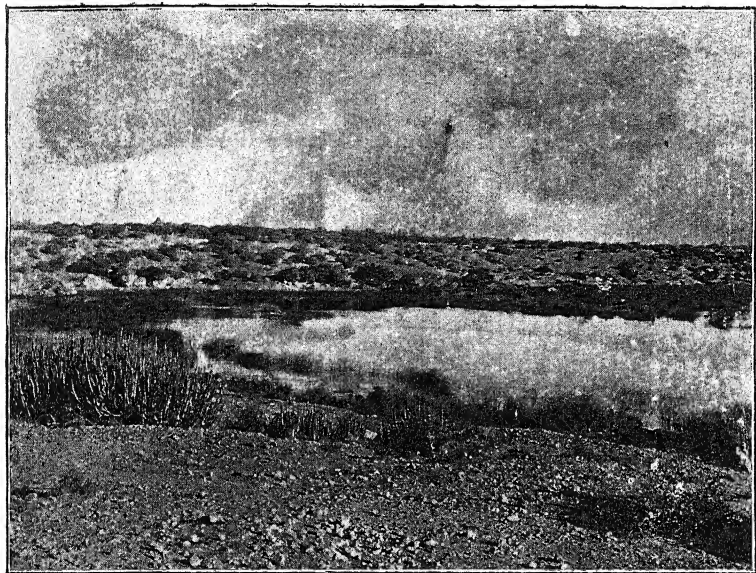
Dicotyledons : Genera 139, species 211

Monocotyledons : " 44, " 67

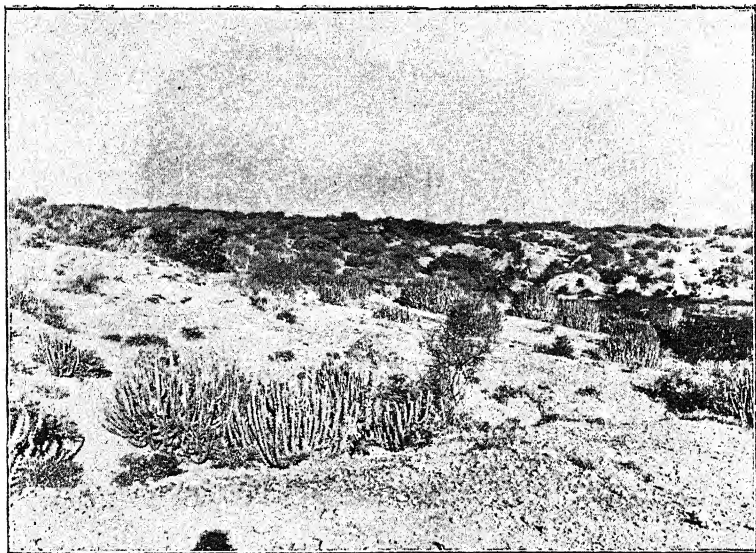
The ratio, therefore, of the Monocotyledons to the Dicotyledons is 1 : 3.14.

The following list shows the families arranged according to the number of species belonging to each :

FAMILIES.	Indig- enous species	Indig- enous genera	FAMILIES.	Indig- enous species	Indi- genous genera
Gramineae ...	40	28	Nyctaginaceae ...	2	1
Leguminosae ...	23	13	Typhaceae ...	2	1
Compositae ...	18	14	Menispermaceae ...	1	1
Convolvulaceae ...	13	5	Cruciferae ...	1	1
Euphorbiaceae ...	11	3	Resedaceae ...	1	1
Amarantaceae ...	11	8	Polygalaceae ...	1	1
Cyperaceae ...	11	4	Caryophyllaceae ...	1	1
Malvaceae ...	10	5	Sterculiaceae ...	1	1
Boraginaceae ...	9	3	Geraniaceae ...	1	1
Tiliaceae ...	8	3	Burseraceae ...	1	1
Asclepiadaceae ...	8	7	Celastraceae ...	1	1
Chenopodiaceae ...	8	6	Rhamnaceae ...	1	1
Cucurbitaceae ...	7	7	Plumbaginaceae ...	1	1
Solanaceae ...	7	5	Myrsinaceae ...	1	1
Scrophulariaceae...	7	6	Apocynaceae ...	1	1
Acanthaceae ...	7	4	Gentianaceae ...	1	1
Capparidaceae ...	6	5	Orobanchaceae ...	1	1
Rhizophoraceae ...	5	3	Bignoniaceae ...	1	1
Zygophyllaceae ...	4	3	Polygonaceae ...	1	1
Ficoidaceae ...	4	3	Aristolochiaceae ...	1	1
Labiatae ...	4	3	Urticaceae ...	1	1
Naiadaceae ...	4	3	Salicaceae ...	1	1
Nymphaeaceae ...	3	2	Gnetaceae ...	1	1
Tamaricaceae ...	3	1	Hydrocharitaceae ...	1	1
Verbenaceae ...	3	3	Amaryllidaceae ...	1	1
Liliaceae ...	3	1	Commelinaceae ...	1	1
Portulacaceae ...	2	1	Palmae ...	1	1
Elatinaceae ...	2	1	Pandanaceae ...	1	1
Lythraceae ...	2	2	Lemnaceae ...	1	1
Goodeniaceae ...	2	1	Alismaceae ...	1	1
Salvadoraceae ...	2	1			

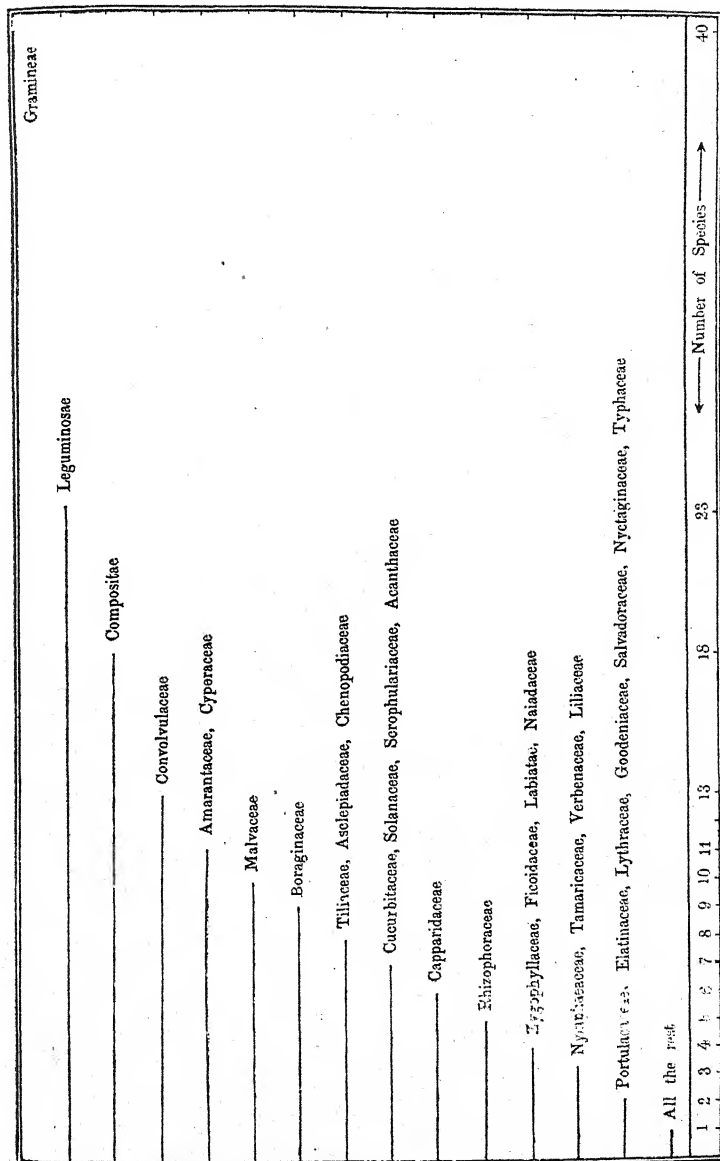


No. 21. Tatta Lake, fringed with sedges; shore rocky and gravelly, covered with *Capparis decidua* Pax and *Euphorbia caducifolia*.



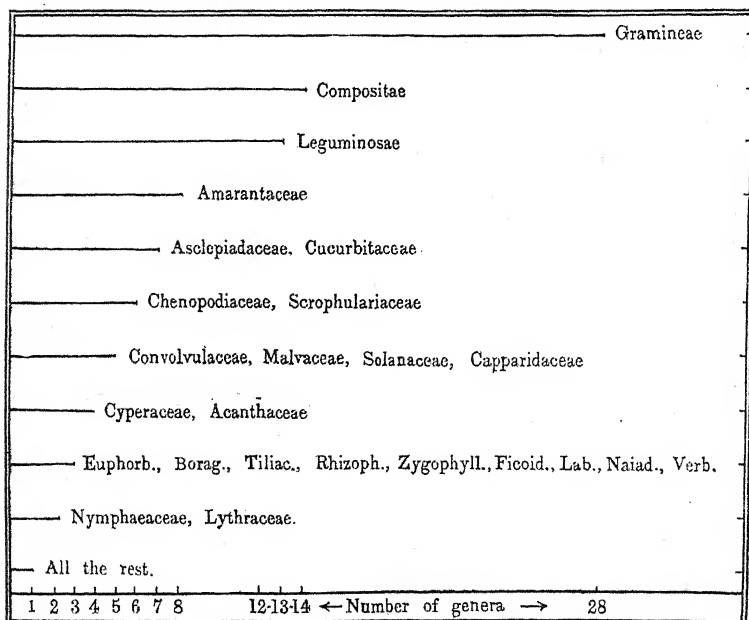
No. 22. An almost pure formation of *Euphorbia caducifolia* on a rocky slope near Tatta.

We show the same graphically (Graph 10):



Graph 10.—To show the number of species belonging to each family.

It is a striking fact that out of 61 families 36 are represented by 1 genus only, and 28 by 1 species. Diagram 11 shows how many genera belong to each family.

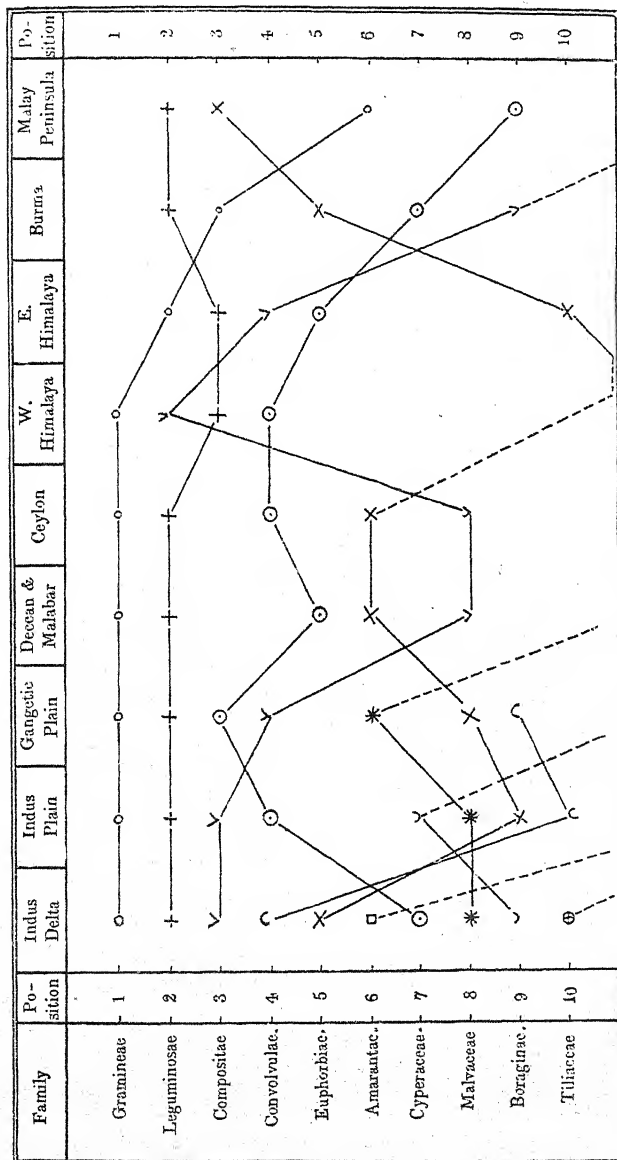


Graph 11.—To show how many genera be'ong to each family.

The following are the dominant families if we consider the number of species belonging to each.

FAMILIES.	Spe- cies	Per- cen- tage of total	FAMILIES.	Spe- cies	Per- cen- tage of total
Gramineæ ...	40	14.3	Malvaceæ ...	10	3.5
Leguminosæ ...	23	8.2	Boraginaceæ ...	9	3.2
Compositæ ...	18	6.4	Tiliaceæ ...	8	2.8
Convolvulaceæ ...	13	4.6	Asclepiadaceæ ...	8	2.8
Euphorbiaceæ ...	11	3.9	Chenopodiaceæ ...	8	2.8
Amarantaceæ ...	11	3.9	Cucurbitaceæ ...	7	2.5
Cyperaceæ ...	11	3.9	Solanaceæ ...	7	2.5

In order to obtain a clearer insight into the relations of the flora of the Indus Delta with other botanical regions of India, Burma and Ceylon, we add a graph showing the distribution of the 10 dominant orders of the Indus Delta in the Indus Plain, the Gangetic Plain, the Deccan and Malabar, Ceylon, the W. Himalaya, the E. Himalaya, Burma and the Malay Peninsula. A glance at the graph will explain the salient features. (Graph 12).



Graph 12.—Distribution of the 10 dominant families of the Indus Delta in various botanical regions.

II. Geographical Distribution.

Out of the 279 indigenous species we have classified 265 according to their geographical distribution. 14 species have not been considered on account of their abnormal and erratic distribution. We distinguish 16 groups:

1. 6 endemic species, viz.

<i>Gossypium Bakeri.</i>	<i>Andrachne</i> sp.
<i>Periploca</i> sp.	<i>Asparagus gharoensis.</i>
<i>Convolvulus</i> sp.	<i>Asparagus deltae.</i>

So far we have to consider them as endemic, but it is more than likely that some day they will be found in the neighbouring countries.

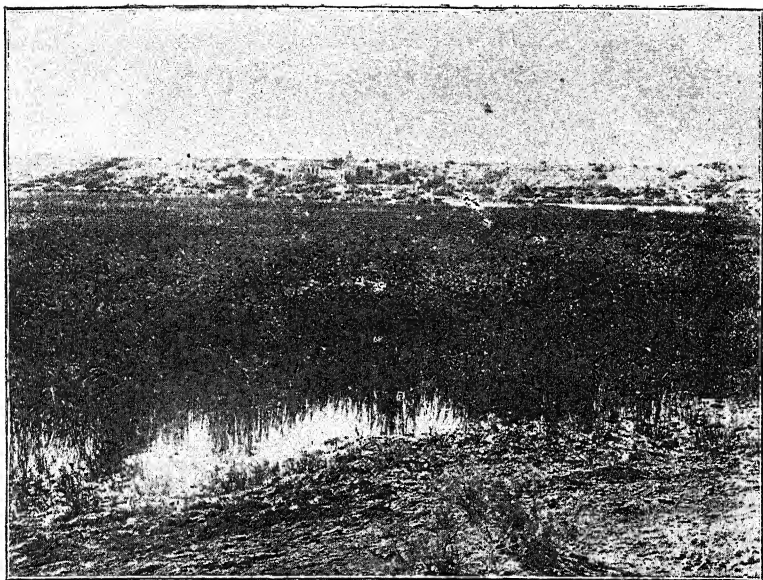
2. The Indian element consisting of 29 species which are found in various parts of India and extend sometimes into Ceylon:

<i>Nymphaea rubra</i>	<i>Trichodesma indicum</i> , var. <i>amplexicaule</i>
<i>Maerua arenaria</i>	
<i>Cadaba indica</i>	<i>Rivea hypocrateriformis</i>
<i>Tamarix dioica</i>	<i>Linaria ramosissima</i>
<i>Triumfetta rotundifolia</i>	<i>Lindenbergia urticaefolia</i>
<i>Indigofera uniflora</i>	<i>Clerodendron Phlomidis</i>
<i>I. viscosa</i>	<i>Suaeda nudiflora</i>
<i>Tephrosia tenuis</i>	<i>Polygonum plebejum</i>
<i>Mimosa hamata</i>	<i>Euphorbia caducifolia</i> *
<i>Kedrostis rostrata</i>	<i>E. Clarkeana</i>
<i>Corallocarpus epigaeus</i>	<i>Ficus glomerata</i>
<i>Pluchea tomentosa</i>	<i>Orinum asiaticum</i>
<i>Echinops echinatus</i>	<i>Pandanus tectorius</i>
<i>Volularella divaricata</i>	<i>Urochloa setigera</i>
<i>Daemia extensa</i>	<i>Oryza coarctata</i>

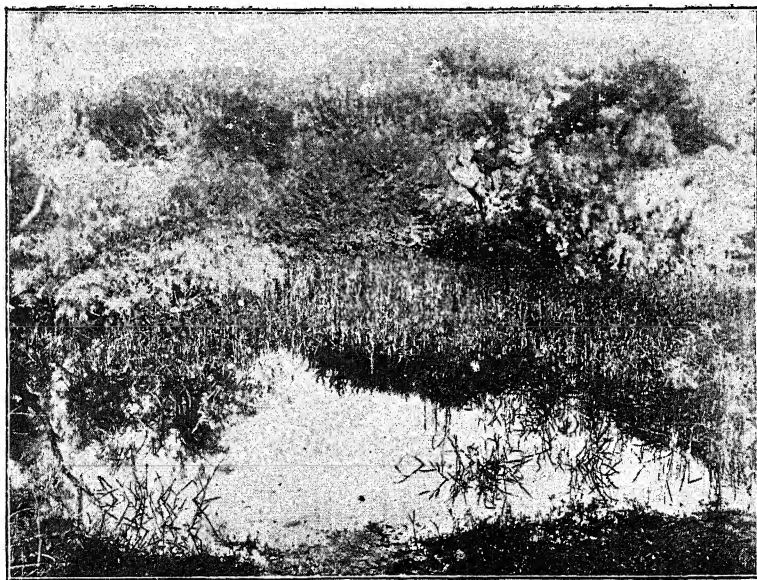
3. The Indo-Malayan Element, consisting of 16 species, some of them extending to Australia and Polynesia:

<i>Crotalaria juncea</i>	<i>Heliotropium paniculatum</i>
<i>C. medicaginea</i>	<i>Solanum xanthocarpum</i>
<i>Indigofera cordifolia</i>	<i>Bonnaya veronicaefolia</i>
<i>Pongamia glabra</i>	<i>Avicennia officinalis</i>
<i>Ceriops Roxburghiana</i>	<i>Cyperus Haspan</i>
<i>Sonneratia acida</i>	<i>Pimbristylis ferruginea</i>
<i>Scaevola frutescens</i>	<i>Coix Lachryma-Jobi</i>
<i>Oryzstela esculentum</i>	<i>Eragrostis amabilis</i>

* *Euphorbia caducifolia* Haines should be substituted for *Euphorbia nivulia* Ham. throughout the series. Mr. C. E. C. Fischer of the Kew Herbarium informs us that our tree-*Euphorbia* is *E. caducifolia* (See Kew Bull. (1925), 341).



No. 23. An almost pure formation of *Cyperaceæ* in an inundated swamp near Tatta.



No. 24. A pool near Kullan Kote Lake. In the water *Panicum*, on the bank *Euphorbia*, *Acacia*, *Tamarix*.

4. Plants belonging to the N. African-Indian Desert. We include also those species which have been found only in the Indian Desert. This is the best-represented group numbering 60 species :

<i>Farsetia Jacquemontii</i>	<i>Convolvulus scindicus</i>
<i>Ochradenus baccatus</i>	<i>C. Rotlerianus</i>
<i>Polycarpaea spicata</i>	<i>C. microphyllus</i>
<i>Tamarix Troupii</i>	<i>Lycium barbarum</i>
<i>Tamarix articulata</i>	<i>Schweinfurthia sphaerocarpa</i>
<i>Gossypium Stocksii</i>	<i>Cistanche tubulosa</i>
<i>Tribulus alatus</i>	<i>Tecomella undulata</i>
<i>Commiphora mukul</i>	<i>Blepharis sindica</i>
<i>Zizyphus rotundifolia</i>	<i>Salvia aegyptiaca</i>
<i>Crotalaria Burhia</i>	(also Mediterranean)
<i>Indigofera anabaptista</i>	<i>Aerva tomentosa</i>
<i>Tephrosia petrosa</i>	<i>A. pseudo-tomentosa</i>
<i>Alhagi camelorum</i>	<i>Atriplex Stocksii</i>
<i>Prosopis spicigera</i>	<i>Suaeda monoica</i>
<i>Cucumis prophetarum</i>	<i>Salsola foetida</i>
<i>Citrullus Colocynthis</i>	<i>Euphorbia granulata</i>
<i>Orygia decumbens</i>	<i>E. jodhpurensis</i>
<i>Pluchea lanceolata</i>	<i>Ephedra foliata</i>
<i>Gnaphalium pulvinatum</i>	<i>Asparagus dumosus</i>
<i>Inula grantioides</i>	<i>Cyperus arenarius</i>
<i>Pulicaria angustifolia</i>	<i>Saccharum Griffithii</i>
<i>P. Stocksii</i>	<i>Cymbopogon Iwarancusa</i>
<i>Launaea chondrilloides</i>	<i>Digitaria pennata</i>
<i>L. nudicaulis</i>	<i>Oenchrus biflorus</i>
<i>Statice Stocksii</i>	<i>Sporobolus arabicus</i>
<i>Salvadora oleoides</i>	<i>Heleochloa dura</i>
<i>Periploca aphylla</i>	<i>Eragrostis ciliaris</i>
<i>Sarcostemma Stocksii</i>	<i>Chloris villosa</i> (also Mediter-
<i>Leptadenia spartium</i>	ranean)
<i>Heliotropium calcareum</i>	<i>Eleusine flagellifera</i>
<i>Heliotropium undulatum</i>	<i>Aeluropus villosus</i> (also Medi-
(also Mediterranean and trop.	terranean)
Asia)	

5. The Tropical and N. African-Indian Desert Element. It is also known under the name of N. African Steppe, and comprises Kordofan, Darfur, Sennaar, Etbai, Abyssinia, Yemen, Hadramaut, and the island of Socotra, and sends a number of representatives into

India, especially the N.-W. part. In the Delta we have 37 species belonging to that group :

<i>Cocculus pendulus</i>	<i>Pentstemon cynanchoides</i>
<i>Oleome brachycarpa</i>	<i>Cordia myxa</i>
<i>Capparis decidua</i>	<i>Cordia Rothii</i>
<i>Polygala irregularis</i>	<i>Heliotropium ophioglossum</i>
<i>Bergia odorata</i>	<i>H. ovalifolium</i> (also Mediter- ranean)
<i>Sida grewioides</i>	<i>Convolvulus rhynchospermus</i>
<i>Abutilon muticum</i>	<i>Solanum albicaule</i>
<i>A. fruticosum</i>	<i>Lindenbergia abyssinica</i>
<i>Senra incana</i>	<i>Ruellia patula</i>
<i>Grewia populifolia</i>	<i>Barleria acanthoides</i>
<i>Corchorus antichorus</i>	<i>B. Hochstetteri</i>
<i>Melhania Denhamii</i>	<i>Leucas urticaefolia</i>
<i>Zygophyllum simplex</i>	<i>Aristolochia bracteata</i>
<i>Acacia arabica</i>	<i>Andrachne aspera</i>
<i>A. Senegal</i>	<i>Commelina albescens</i>
<i>Vernonia cinerascens</i>	<i>Cenchrus catharticus</i>
<i>Dicoma tomentosa</i>	<i>Aristida funiculata</i>
<i>Salvadora persica</i>	<i>Eleusine aristata</i>
<i>Calotropis procera</i>	

6. This group comprises 13 species which are common to tropical Africa and India :

<i>Nymphaea stellata</i>	<i>Arthrocnemum indicum</i>
<i>Grewia asiatica</i>	<i>Typha elephantina</i> (also N. Africa)
<i>G. villosa</i>	<i>Cyperus tegulum</i>
<i>Triumfetta pentandra</i>	<i>Pennisetum cenchroides</i> (also Mediterranean)
<i>Trianchema pentandra</i>	<i>Desmostachya cynosuroides</i> (also Syria)
<i>Ruellia prostrata</i> var. <i>dejecta</i>	
<i>Justicia heterocarpa</i>	
<i>Nothosaerua brachiata</i>	

7. Common to the Tropics of the Old World are 39 species :

<i>Portulaca quadrifida</i>	<i>Sesbania aculeata</i>
<i>Bergia ammannioides</i>	<i>Aeschynomene indica</i>
<i>Abutilon polyandrum</i>	<i>A. aspera</i>
<i>Thespesia populnea</i>	<i>Alysicarpus vaginalis</i>
<i>Corchorus tridens</i>	<i>Rhizophora mucronata</i>
<i>Gymnosporia montana</i>	<i>R. conjugata</i>
<i>Indigofera paucifolia</i>	<i>Ceriops Candolleana</i>

<i>Bruguiera gymnorrhiza</i>	<i>Boerhaavia verticillata</i>
<i>Momordica Charantia</i>	<i>Pupalia lappacea</i>
<i>Coccinia indica</i>	<i>Alternanthera nodiflora</i>
<i>Melothria maderaspatana</i>	<i>Phyllanthus reticulatus</i> (also
<i>Vernonia cinerea</i>	China)
<i>Enicostemma littorale</i> (also W.	<i>Cyperus stoloniferus</i>
Indies)	<i>C. alopecuroides</i>
<i>Merremia chrysoides</i>	<i>Saccharum spontaneum</i>
<i>Ipomoea eriocarpa</i>	<i>Dichanthium annulatum</i>
<i>I. aquatica</i>	<i>Paspalum scrobiculatum</i> var.
<i>Physalis minima</i>	<i>Commersonii</i>
<i>Limnophila gratioloides</i>	<i>Phragmites karka</i> (also Japan)
<i>Barleria Prionitis</i>	<i>Eragrostis interrupta</i> var.
<i>Ocimum canum</i>	Koenigii
	<i>Diplachne fusca</i>

8. Common to the Tropics generally are 19 species:

<i>Oleome viscosa</i>	<i>Datura fastuosa</i>
<i>Gynandropsis pentaphylla</i>	<i>Amarantus viridis</i>
<i>Abutilon indicum</i>	<i>Achyranthes aspera</i>
<i>Corchorus acutangulus</i>	<i>Euphorbia hypericifolia</i>
<i>Ehynchosia minima</i>	<i>Phyllanthus Niruri</i>
<i>Acacia Farnesiana</i>	<i>Cocos nucifera</i>
<i>Trianthema monogyna</i>	<i>Eleocharis atropurpurea</i>
<i>Blainvillea rhomboidea</i>	<i>Paspalidium geminatum</i>
<i>Merremia aegyptia</i>	<i>Chloris barbata</i>
<i>Ipomoea biloba</i>	

9. Occurring in most warm countries are the following 22 species:

<i>Portulaca oleracea</i>	<i>Vallisneria spiralis</i>
<i>Sida spinosa</i>	<i>Cyperus rotundus</i>
<i>Tribulus terrestris</i>	<i>Hemarthria compressa</i>
<i>Fagonia cretica</i>	<i>Digitaria sanguinalis</i>
<i>Mollugo hirta</i>	<i>Eriochloa ramosa</i>
<i>Eclipta erecta</i>	<i>Echinochloa colona</i>
<i>Sonchus oleraceus</i>	<i>E. stagnina</i>
<i>Scaevola Plumierii</i>	<i>Setaria verticillata</i>
<i>Oressa cretica</i>	<i>Aristida Adscensionis</i>
<i>Amarantus polygamus</i>	<i>Tragus racemosus</i>
<i>Alternanthera triandra</i>	<i>Cynodon dactylon</i>

10. 6 species are found in the tropical and subtropical regions of the Old World or of the whole world :

<i>Grangea maderaspatana</i>	<i>Boerhaavia diffusa</i>
<i>Lippia nodiflora</i>	<i>Euphorbia hirta</i>
<i>Ocimum sanctum</i>	<i>E. pilulifera</i>

11. In the warm parts of the Old World we find 3 species :

<i>Ammannia baccifera</i>	<i>Eleusine aegyptiaca</i>
<i>Fimbristylis dichotoma</i>	

12. One species is common to the temperate and subtropical regions :

Zanichellia palustris

13. Mediterranean—Oriental 2 species :

<i>Withania somnifera</i>	<i>Saccharum Ravennae</i>
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14. Oriental 5 species :

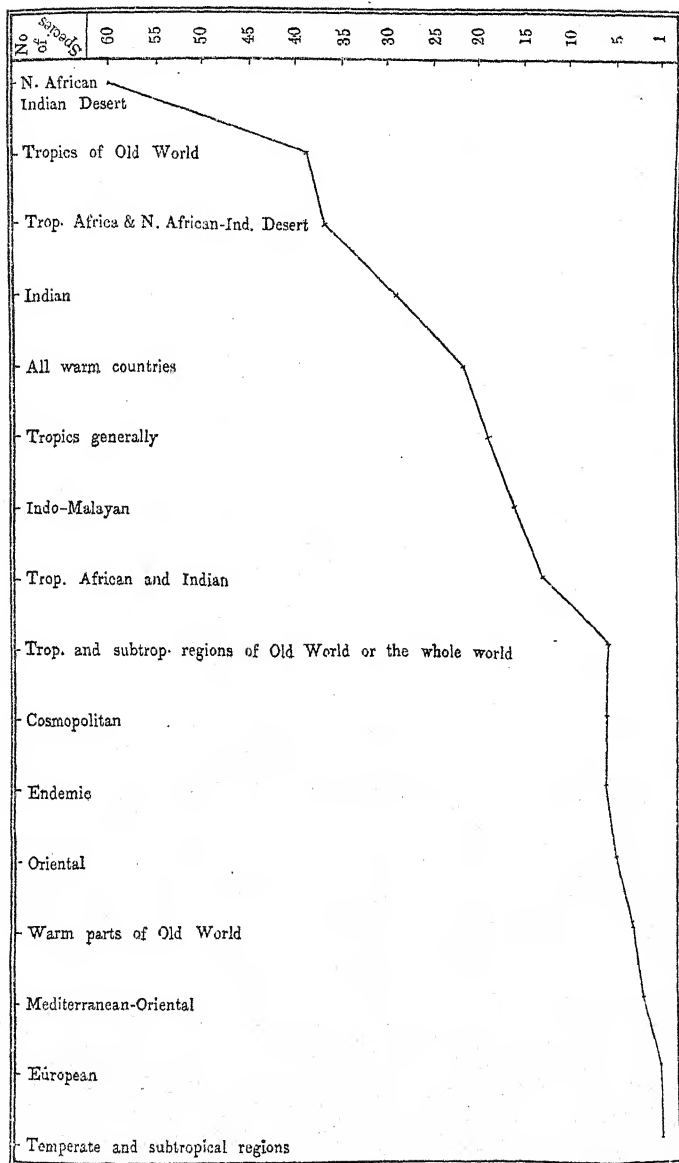
<i>Taverniera cuneifolia</i>	<i>Haloxyton recurvum</i>
<i>Nerium odorum</i>	<i>Populus euphratica</i>
<i>Suaeda fruticosa</i> (also Europe, N. Africa and America)	

15. European 1 species : *Erodium cicutarium*.

16. Cosmopolitan 6 species :

<i>Convolvulus arvensis</i>	<i>Sagittaria sagittifolia</i>
<i>Solanum nigrum</i>	<i>Scirpus maritimus</i>
<i>Chenopodium murale</i>	<i>Echinochloa Crus-Galli</i>

The following graph 13 shows at a glance to what extent the various floristic areas of the globe are represented in the Indus Delta.



Graph 13.

We can readily distinguish 3 well-marked elements in the flora of the Delta: an eastern, a western, and a more general element including those species which are purely Indian.

THE EASTERN ELEMENT

Indo-Malayan	16 species
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THE WESTERN ELEMENT

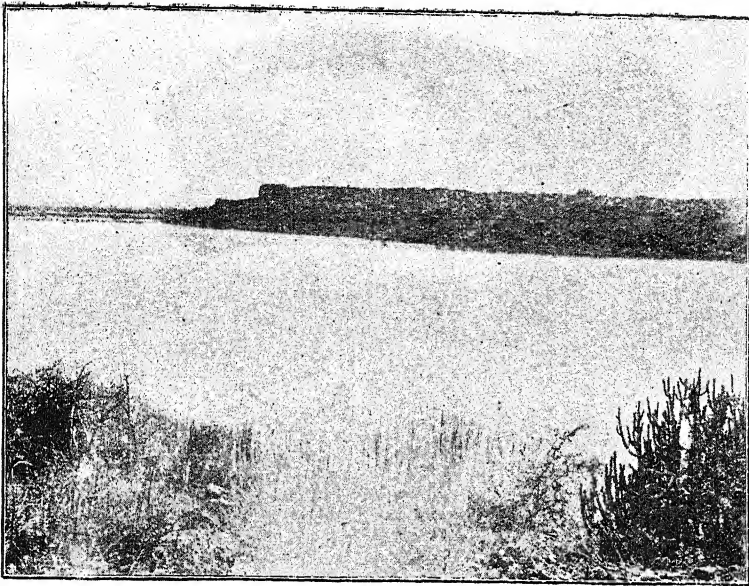
N. African-Indian Desert	60 species
Trop. Africa and N. African-Indian Desert	37 "
Trop. African and Indian	13 "
Oriental	5 "
Mediterranean-Oriental	2 "
European	1 "
<hr/>	
Total ...	118 species
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THE GENERAL ELEMENT :

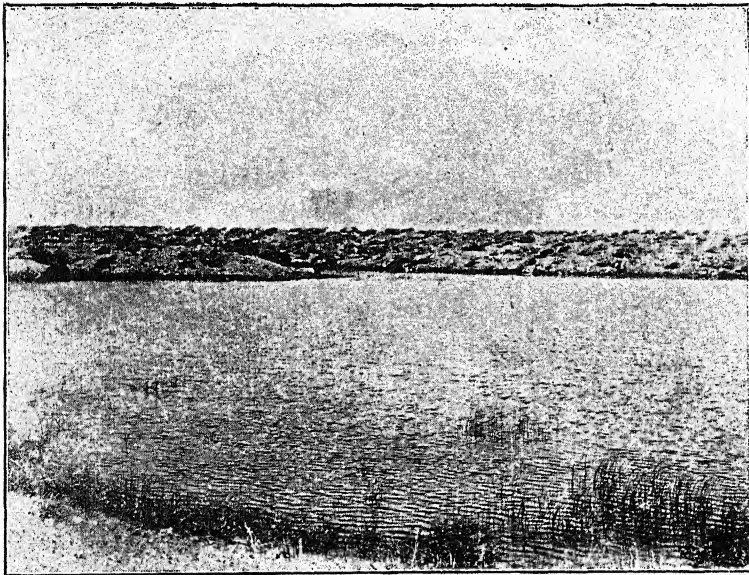
Endemic	...	6 species
Indian	...	29 "
Tropics of Old World	...	39 "
Tropics generally	...	19 "
Warm parts of Old World .	...	3 "
All warm countries	...	22 "
Tropical and subtrop. regions of the Old World or of the whole world	...	6 "
Temperate and subtrop. regions	...	1 "
Cosmopolitan	...	6 "
<hr/>		
Total ...	131	"
<hr/>		

We are allowed to neglect the general element for our purposes, as it consists of species which are either only Indian or show a wider distribution over the eastern and western parts of the Old World, or comprise even certain regions of the whole globe.

What is left to form an estimate of the plant-geographical position of the flora is the western element with 118 species, and the eastern (Indo-Malayan) with 16 species. The eastern forms just a little more than $\frac{1}{7}$ of the western. The ecological conditions of the Delta are not such as to exclude Indo-Malayan types entirely, but the western (chiefly African) element is vastly preponderant.

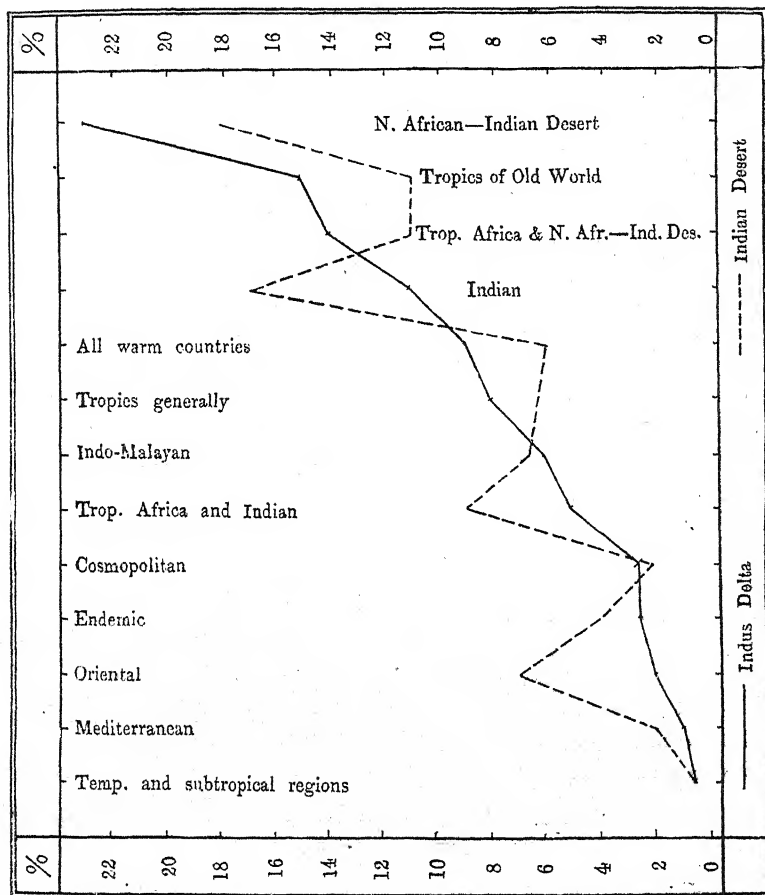


No. 25. Kullan Kote Lake. In foreground: Sedges, *Euphorbia*, *Capparis*. In background: A rocky hill with *Acacia*, *Grewia*, *Zizyphus*.



No. 26. Kullan Kote Lake. Mixed formation of *Euphorbia caducifolia*, *Commiphora mukul*, *Acacia Senegal*, *Zizyphus*; shrubby *Acanthaceae*.

A comparison of the vegetation of the Indus Delta with that of the Indian Desert (Jodhpur and Jaisalmer of which states alone we possess detailed information) is not without interest. Graph 14 speaks for itself.



Graph 14.

III. Origin of the flora.

The flora of the Indus Delta, except a narrow strip along the northern border and a small rocky area in the Tatta district and south of Tatta is, judging from its geographical position and geological condition, of very recent origin, taking recent in its geological sense.

Of the 279 species that make up its flora 226 are found in other parts of Sind. This latter number will very likely grow with the increased knowledge of the vegetation of Sind.

These are the 54 species, which, according to the data at present at our disposal,¹ have not been observed in extra-deltaic Sind:

<i>Nymphaea stellata</i>	<i>Chenopodium murale</i>
<i>Nelumbium speciosum</i>	<i>Euphorbia pilulifera</i>
<i>Maerua arenaria</i>	<i>E. jodhpurensis</i>
<i>Abutilon polyandrum</i>	<i>Andrachne</i> sp.
<i>Gossypium Bakeri</i>	<i>Ficus glomerata</i>
<i>Triumfetta rotundifolia</i>	<i>Populus euphratica</i>
<i>T. pentandra</i>	<i>Crinum asiaticum</i>
<i>Indigofera uniflora</i>	<i>Asparagus gharoensis</i>
<i>Aeschynomene indica</i>	<i>A. deltae</i>
<i>A. aspera</i>	<i>Commelina albenscens</i>
<i>Rhizophora mucronata</i>	<i>Pandanus tectorius</i>
<i>R. conjugata</i>	<i>Typha elephantina</i>
<i>Ceriops Roxburghiana</i>	<i>Lemna</i> sp.
<i>Bruguiera gymnorhiza</i>	<i>Sagittaria sagittifolia</i>
<i>Sonneratia acida</i>	<i>Aponogeton monostachyon</i>
<i>Kedrostis rostrata</i>	<i>Naias</i> , 2 species
<i>Vicoa cernua</i>	<i>Cyperus stoloniferus</i>
<i>Periploca</i> sp.	<i>C. Haspan</i>
<i>Trichodesma indicum</i>	<i>Eleocharis atropurpurea</i>
<i>Convolvulus</i> sp.	<i>Saccharum Griffithii</i>
<i>Merremia aegyptia</i>	<i>Urochloa setigera</i>
<i>Limnophila gratioloides</i>	<i>Echinochloa Orus-Galli</i>
<i>Bonnaya veronicaefolia</i>	<i>E. stagnina</i>
<i>Lindenbergia urticaefolia</i>	<i>Cenchrus catharticus</i>
<i>Ruellia prostrata</i>	<i>Eragrostis amabilis</i>
<i>Avicennia officinalis</i>	<i>Diplachne fusca</i>
<i>Ocimum sanctum</i>	

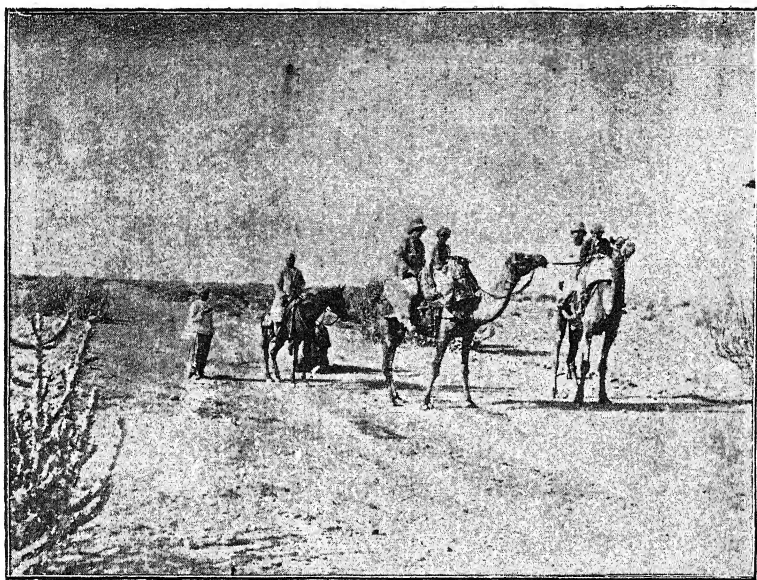
In the above list there are 6 endemic species which we have already mentioned. Cutch could contribute at least 8 species:

<i>Nymphaea stellata</i>	<i>Bruguiera gymnorhiza</i>
<i>Triumfetta rotundifolia</i>	<i>Avicennia officinalis</i>
<i>Rhizophora mucronata</i>	<i>Euphorbia pilulifera</i>
<i>R. conjugata</i>	<i>Pandanus tectorius</i>

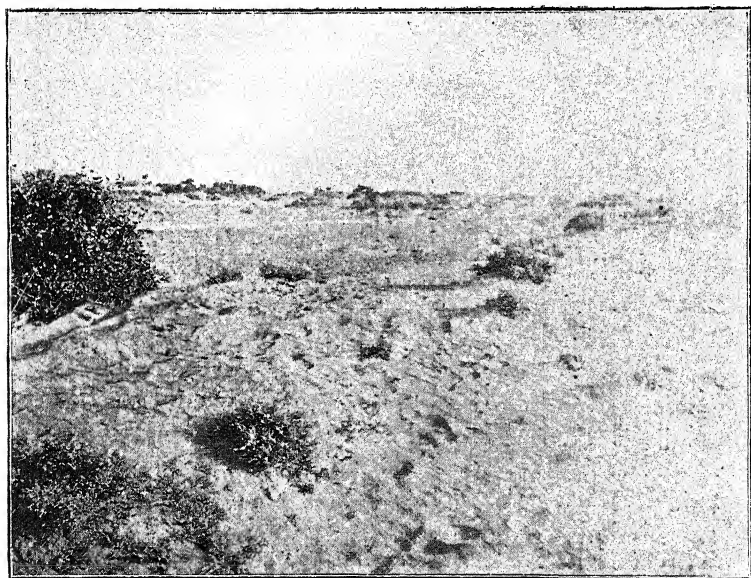
Cutch is only partly known² and it is more than likely that other species may have reached the Delta via Cutch.

¹ T. S. Sabnis, The Flora of Sind. Journ. Ind. Bot. Soc., vol. III, p. 151, etc.

² E. Blatter. On the Flora of Cutch. Journ. Bomb. Nat. Hist. Soc. XVIII (1908), 756-777; XIX (1909), 157-176.



No. 27. Barren rocky undulating plain between Gholam and Tatta with only *Capparis decidua* and *Euphorbia caducifolia*.



No. 28. Sand-dune near Gharo with *Calotropis procera*, *Leptadenia spartium*, *Asparagus gharoensis*.

The Rajputana Desert ³ can be held responsible for the presence of the following species in the Delta :

<i>Merremia aegyptia</i>	<i>Euphorbia jodhpurensis</i>
<i>Lindenbergia urticaefolia</i>	<i>Eleocharis atropurpurea</i>
<i>Ocimum sanctum</i>	<i>Genchrus catharticus</i>

We seem to be justified in tracing

<i>Maerua arenaria</i>	<i>Typha elephantina</i>
<i>Populus euphratica</i>	<i>Sagittaria sagittifolia</i>

to the Punjab, and the following species to Baluchistan :

<i>Trichodesma indicum</i>	<i>Oenopodium murale</i>
<i>Limnophila gratioloides</i>	<i>Saccharum Griffithii</i>

always assuming that the plants in their migrations follow the principle of least resistance.

The W. coast of the Peninsula must have supplied the following members to the mangrove-vegetation of the Delta, in addition to those which we have mentioned as coming from Cutch :

<i>Ceriops Roxburghiana</i>	<i>Sonneratia acida</i>
-----------------------------	-------------------------

We have now accounted for 31 out of the 54 species which do not occur in extra-deltaic Sind. As to the 23 remaining species they have a varied distribution in different parts of Gujarat, the Konkan and the Deccan. Before entering into useless speculations as to how they may have reached the Indus Delta, we prefer awaiting a more complete record of the vegetation of Kathiawar, Cutch and especially of the country lying south of the Marwar-Hyderabad railway line.

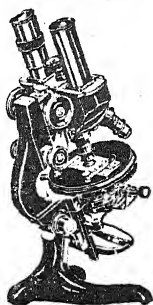
It is not difficult to trace the path which the Indo-Malayan and Indian plants east of Sind followed in their migration through West India, Rajputana and the Punjab.

For the immigration into Sind of all the western species we refer to Agharkar ⁴ who has studied the means of dissemination of the xerophytes, subxerophytes and halophytes of the flora of N. W. India and has discussed all the possible ways by which western plants, especially African, could enter the Indus plain.

(To be continued.)

³ E. B'atter and F. Hallberg. The Flora of the Indian Desert. Journ. Bomb. Nat. Hist. Soc. XXVI (1918), 218-246; XXVI (1919), 525-551, 811-818; XXVI (1920), 968-987; XXVII (1920), 40-47, 270-279; XXVII (1921), 506-519.

⁴ S. Agharkar, Ueber die Verbreitungsmittel der Xerophyten, Subxerophyten und Halophyten des Nordwestlichen Indiens und ihre Herkunft. In Botanische Jahrbuecher (1920) Beiblatt 124.



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VOL. VII.

JULY, 1928.

No. 2.

SHOOT-BUDS FROM ROOT-CUTTINGS.

BY T. S. SABNIS,

Economic Botanist to the Government, United Provinces.

It is the object of this paper to record the observations of the writer about the varied mode of orientation of shoot-buds from root-cuttings, with a note on the mode of their origin in the root. It is not possible to suggest, at this stage, any general rule bearing on the behaviour of root-cuttings as a whole. The problem of reversion and general behaviour of plants raised from the root-cuttings of variegated plants will be discussed in a later paper.

Method :—The medium found suitable for root-cuttings is about two inches of loose sand on the top, with light garden loam below; it is however necessary to see that the pots do not get water-logged. The pots are placed at a temperature of 60°F so that there is sufficient moisture and warmth. The cuttings should be placed about half to three-fourth inch deep.

The time of budding for root-cuttings of different plants varies considerably, the shortest time being 6-7 days as seen in *Euphorbia Cyparissias*, *Geranium macrodenum* and *Nasturtium sylvestre*; *Maelura aurantiaca*, among plants so far observed, takes the longest time to bud from the roots viz. 4-5 months. As a rule about three weeks is a normal period. It should, however, be noted that the period for budding is fixed for each species. The failure in some cases is due to the susceptibility of roots to some kind of rot as seen in *Acanthus mollis*, *Ailanthus glandulosa*, *Populus alba*, *Populus eugenia* and *Verbascum cupreum*. In these cases roots completely rot at either

end, especially so at the proximal end; and buds, even if they appear, are stopped from further growth. Lateness in some cases is due to the wrong position of the cuttings in the sand-bed, which are usually placed horizontally. Cuttings in these cases prefer a vertical position with proximal end upwards. This was clearly seen in the case of *Tecoma radicans*—horizontally placed cuttings taking over 37 days while the vertically placed ones about 14 days. The cuttings of plants—e.g. *Anchusa italica*, *Acanthus mollis*, *Papaver orientale*, *Rumex alpinus* and *Verbascum phoenicum*—with a tendency to bud in a ring round the xylem at the proximal end prefer a vertical position. One cannot, however, predict beforehand the mode of budding nor the position preferred by the cuttings.

Mode of budding:—The buds may appear either (1) laterally as seen in the greater number of cases; or (2) terminally in a ring round the xylem at the proximal end as in *Anchusa italica* (fig. 1), *Acanthus mollis*, *Erodium macradenum* (fig. 2), *Papaver orientale*, *Populus alba*, *Populus eugenia*, *Picris hieracioides*, *Rumex alpinus*, *Crombe maritima* (fig. 6), *Spiraea ulmaria* and *Verbascum phoenicum* (fig. 4); or (3) singly at the terminal end round the xylem as in *Maclura aurantiaca*, *Senecio pulcher* (fig. 5), *Spiraea filipendulina*, *Taraxacum officinale*; or (4) laterally but towards the proximal end as in *Anemone bulbensis*, *Ajuga reptans* var. *purpurea*, *Ailanthus glandulosa*, *Aristolochia Clematitis*, *Barbarea vulgaris*, *Nasturtium sylvestre* (fig. 3), *Pelargonium Volutis* and *Romneya coulteri* x *R. trichocalyx*.

Distinct polarity is seen in most of the cuttings which have a tendency to bud centrally round the xylem at the proximal end. Some of the cuttings of *Taraxacum officinale*, which buds in this fashion, were placed vertically with proximal end downwards to see whether the mode of budding would vary. It was, however, interesting to see that the bud appeared from the proximal end in a ring in spite of the unfavourable position (fig. 7).

It was thought that anatomy would shed some light on the varied behaviour of the root-cuttings; but no definite structural peculiarities could be seen. Except perhaps in *Gaillardia* var. "*Lady Rolleston*" (fig. 8), the buds were endogenous. They started either (1) quite from the centre of the wood-cylinder, the most deeply seated ones being found in *Barbarea vulgaris* (figs. 9, 10), *Bocconia cordata* (fig. 11), *Cnicus arvensis* (fig. 12), *Convolvulus arvensis* (fig. 13) and *Geranium sanguineum* (fig. 14); or (2) from just inside the pericycle as in *Bouvardia* var. "*President Cleveland*" (fig. 15), *Erodium macradenum* (fig. 16), *Euphorbia Cyparissias* (fig. 17), *Papaver orientale* and *Verbascum phoenicum* (fig. 18).

It was further observed that the woody tissue in cuttings which were characterised by polarity was comparatively poor, sclerenchyma being considerably reduced.

It seems that the woody tissue greatly influences the formation of shoot-buds and its feeble development accounts for the failure of cuttings of *Cochlearia*, Peas and other herbaceous plants. It is perhaps possible to raise plants from the tender roots of these plants which cannot survive in the sand bed the resting period required for the development of buds, by manipulation of temperature so as to quicken the process of bud-formation.

The writer is indebted to the late Prof. Bateson for his kindly interest and to the staff of the John Innes Horticultural Institute, Merton, London, for their consistent help throughout the progress of the work. Thanks are also due to Mr. Osterstock, the artist of the Institute, for photographs of root-cuttings.

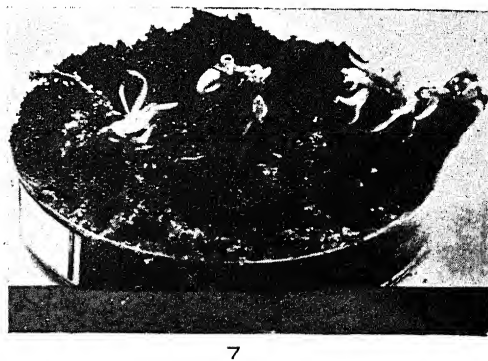
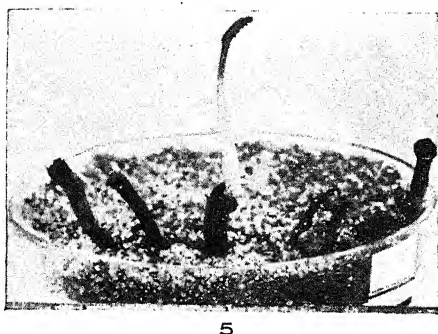
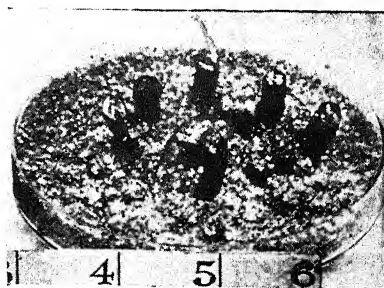
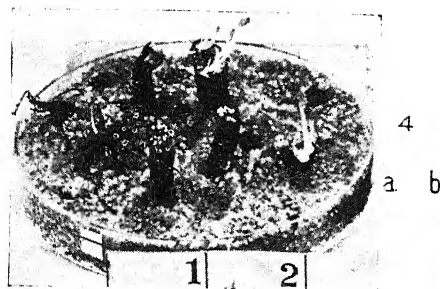
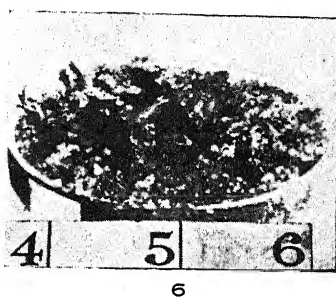
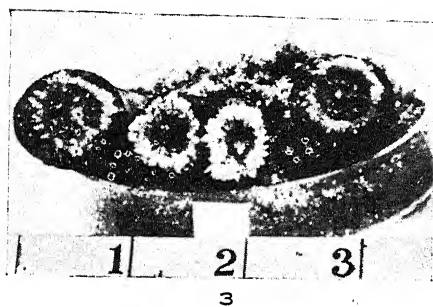
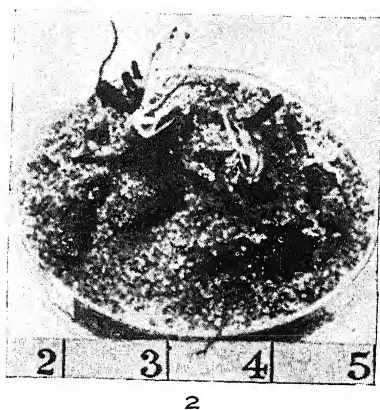
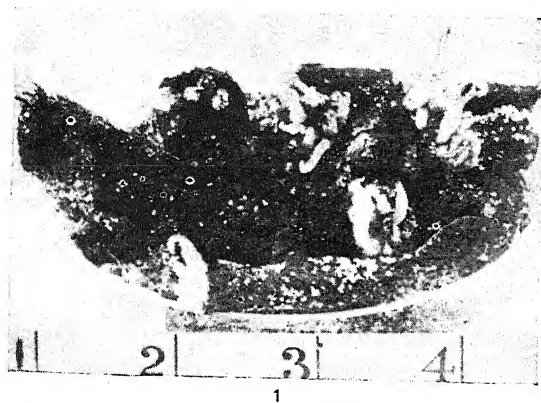
Summary.

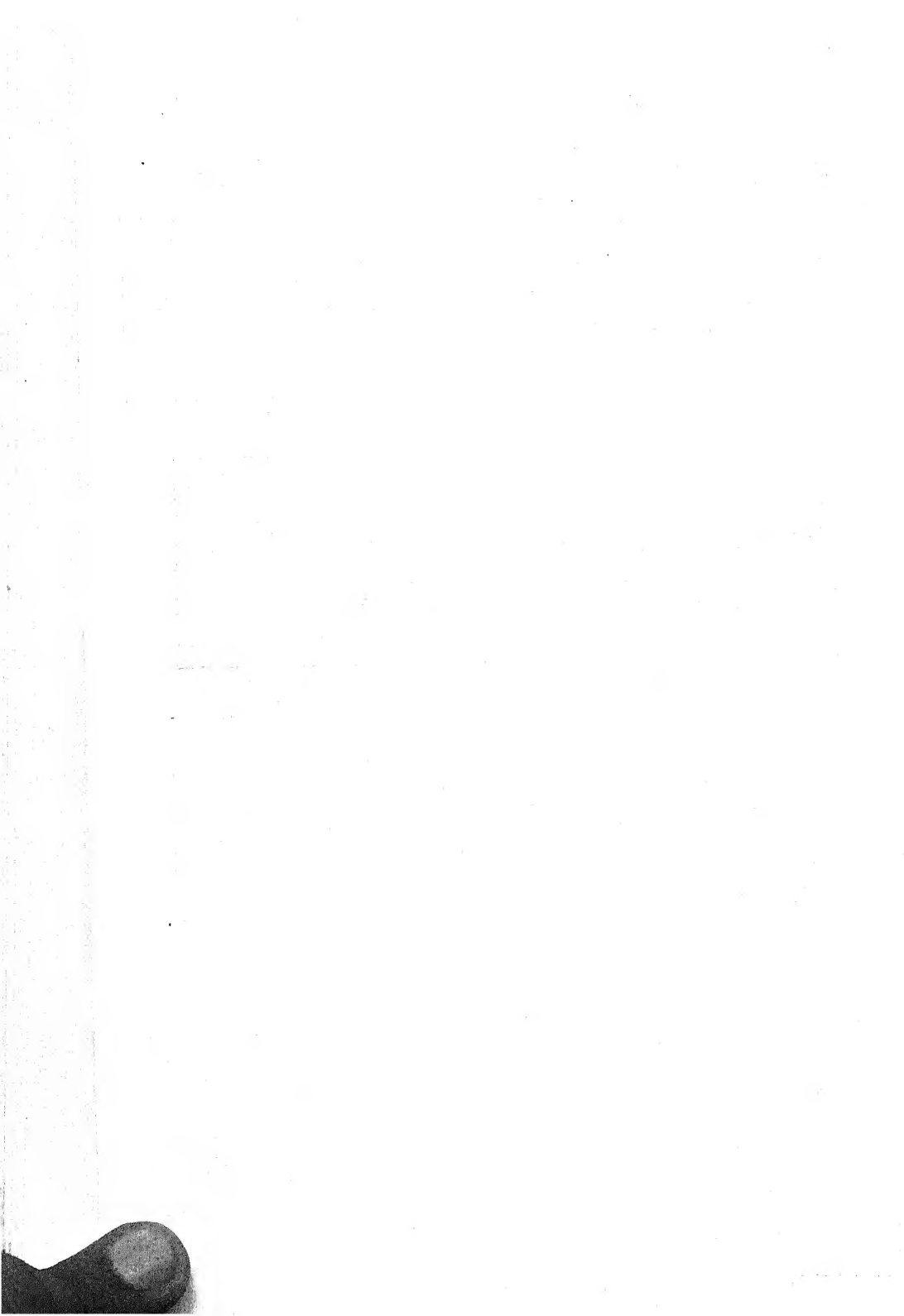
- I. Loose sand on top of light loam forms a good medium for root-cuttings.
- II. Position of cuttings in sand-bed, time of budding, as well as mode of orientation of shoot-buds varies in different plant species.
- III. Polarity correlates with the tendency to bud centrally.
- IV. Anatomy helps in the study of the origin of shoot-buds from root-cuttings.
- V. Woody tissue greatly influences the formation of shoot-buds from root-cuttings.
- VI. Manipulation of temperature may help in raising plants from root-cuttings with feeble development of woody tissue.

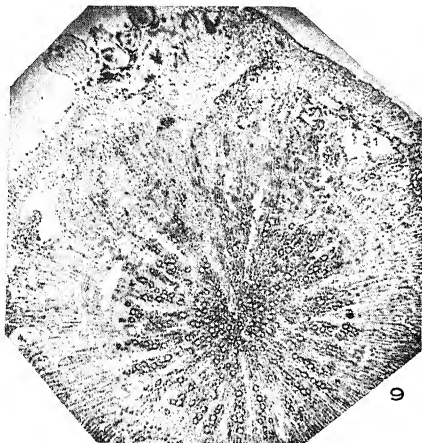
Explanation of figures. (Plates I—III.)

- Fig. 1. *Anchusa italica* var. *dropmore*, showing distinct polarity.
- Fig. 2. *Erodium macradenum* var. *roseum*, showing buds in a ring from the proximal end.
- Fig. 3. *Nasturtium sylvestre*, with shoot-buds arranged laterally in a ring round the edge of the proximal end.
- Fig. 4a. *Verbascum phoenicum* showing distinct polarity.
- Fig. 4b. *Verbascum phoenicum* var. *album*, showing polarity.

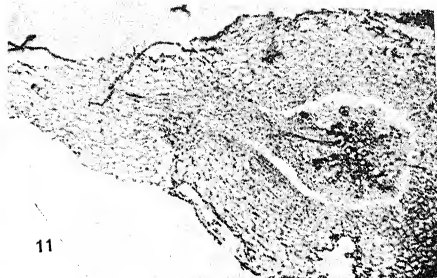
- Fig. 5. *Senecio pulcher*, showing shoot-buds appearing terminally but singly from the wood.
- Fig. 6. *Crombe maritima* (Seakale), showing shoot-buds arranged in regular rings round the wood at the proximal end.
- Fig. 7. *Taraxicum officinale*, cuttings placed upside down vertically. Shoot-buds curving upwards.
- Fig. 8. *Gaillardia* var. "Lady Rolleston," T. S.
- Fig. 9. *Barbarea vulgaris*, T. S.
- Fig. 10. *Barbarea vulgaris*, L. S.
- Fig. 11. *Boeconia cordata*, T. S.
- Fig. 12. *Onicus arvensis* var. *setosus*, T. S.
- Fig. 13. *Convolvulus arvensis*, T. S.
- Fig. 14. *Geranium sanguineum*, T. S.
- Fig. 15. *Bouvardia* var. "President Cleveland," T. S.
- Fig. 16. *Erodium macradenum* var. *roseum*, L. S.
- Fig. 17. *Euphorbia Cyparissias*, L. S.
- Fig. 18. *Verbascum phoenicum*, T. S.



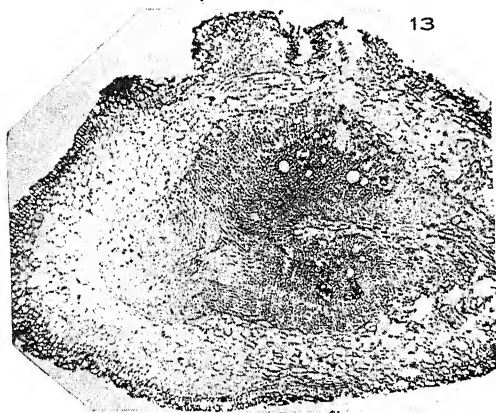




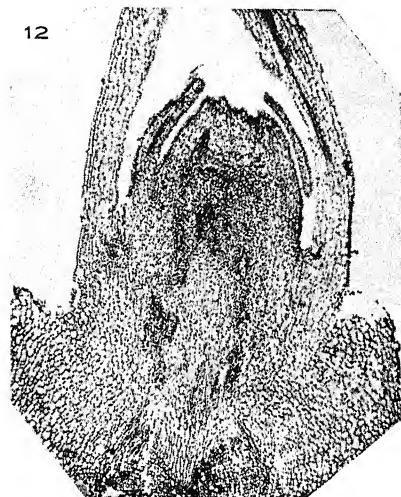
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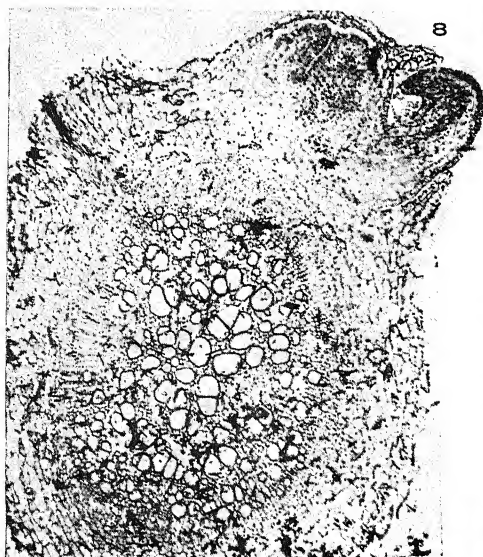
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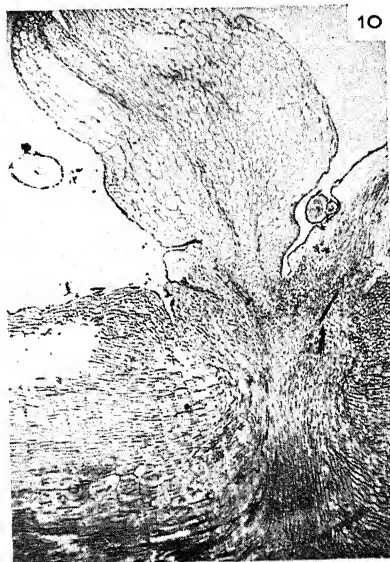
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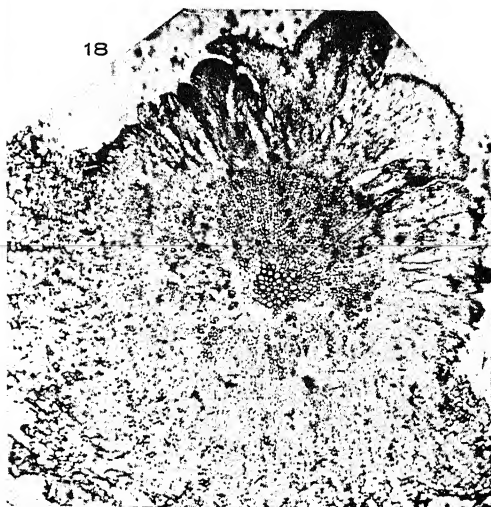
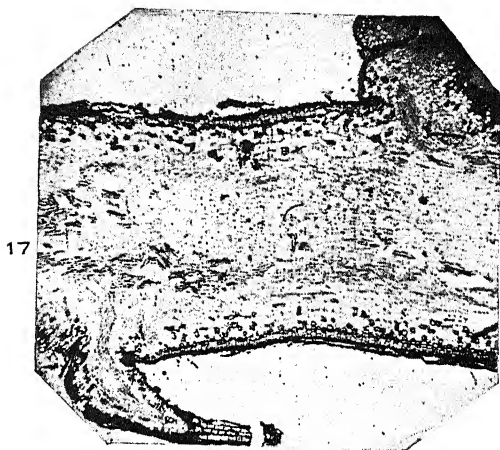
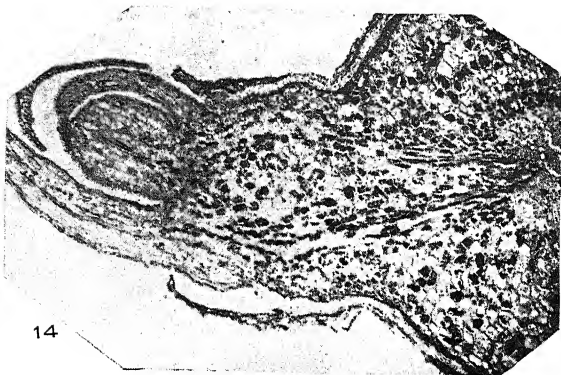
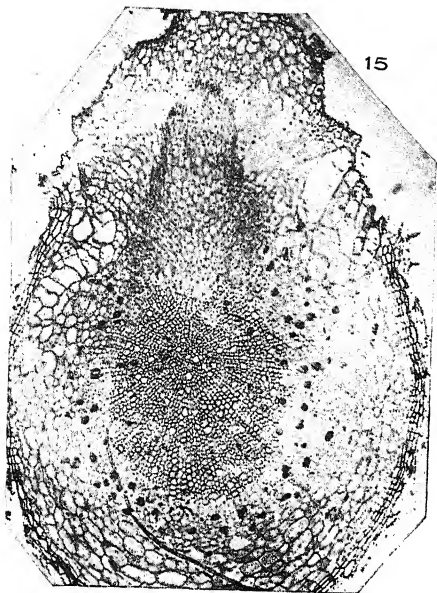
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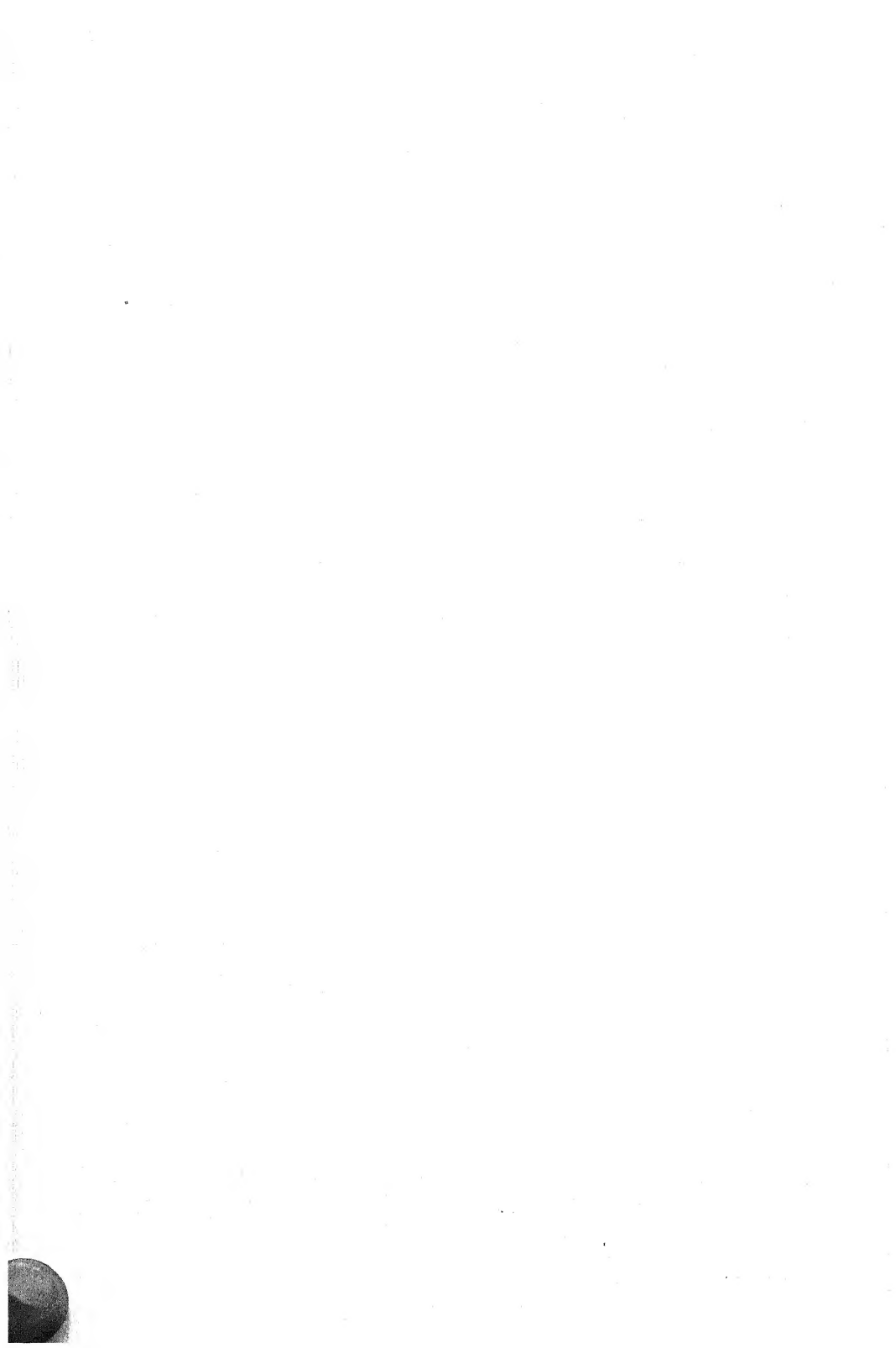


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CHAROPHYTE NOTES FROM SAHARANPUR, U. P.

BY

G. O. ALLEN, I. C. S.

The following notes comprise the main results of my pond hunting in quest of charophytes subsequent to the period covered by my previous paper ¹. For much of what interest my observations may possess I am, as will be seen, indebted to Mr. Groves.

To my great relief I found myself posted on my return from leave in October, 1923, to the Saharanpur District, my experience of the so-called "cool end" of the United Provinces having been only too limited. This spot is far removed from Gonda and enjoys a climate much more congenial to Europeans though it bears rather a bad reputation for fever. The average rainfall is about 39 inches. Frost of any severity is very uncommon and the maximum shade temperature seldom exceeds 105° in a normal year.

The district forms part of the Meerut civil division and comprises the northernmost portion of the Doab, the tract that lies between the Ganges and Jumna rivers and stretches South and then East as far as their junction at Allahabad. These two rivers form respectively the E. and W. boundaries of the Saharanpur District. Across the Jumna to the West lies the Punjab: to the North of the District that charming vale, Dehra Dun, the dividing line between them being the rugged miniature mountain range of the Siwaliks of geological fame. The actual bearings of the district are about 30° North and 78° East.

In its general appearance the district presents a much greater variety than the typical Gangetic plain. Particularly fascinating features are the two canals, the Ganges and the Eastern Jumna, with the refreshing belts of vegetation that fringe their banks. Gazing to the North on a clear day the eye rests first of all on the Siwaliks some thirty miles away and then on the Mussoorie range and beyond that on the peaks of the snow-clad Himalayas.

Most of the district is upland in character, the land sloping on either side down to the low-lying valleys, full of swamps and backwaters. As at Gonda I have been obliged from lack of opportunity to confine my attention mainly to a few small patches of water within easy reach of the civil station which is situated in this upland

¹ Notes on Charophytes from Gonda U. P. (*Journ. Bombay Nat. Hist. Soc.* June 30, 1925).

portion. This limited tract of country is not nearly so well supplied as Gonda with facilities for the study of aquatic plant life, the majority of the more accessible pools being small and soon drying up as the hot weather approaches. That as much as 7 per cent of the district is covered with water is mainly due to the two big rivers and the canals. Towards the Siwaliks ponds are very scarce, a prominent feature being the typical "raos" (torrent beds) usually dry or almost so except during the rains.

The more favourable localities within easier reach I have often visited throughout four cold weathers: for with the onset of the hot weather expeditions rapidly become less profitable from the point of view of charophytes, a general decay of cold season vegetation setting in as ponds rapidly dry up. A more concentrated attention devoted to a small area has however advantages of its own. Several promising spots were lost to me the third and fourth seasons from the rains ceasing rather early. To a somewhat lesser degree my pond hunting extended over the rainy seasons also.

The following is a list of the species collected by me here, those previously recorded being arranged in the order given in Mr. Groves' Notes on Indian Charophyta¹ which paper I assume to be in the hands of the reader. The references opposite them are to the more readily accessible published illustrations.

<i>N. mirabilis</i>	...	Notes on Indian Charophyta; Notes on Charophytes from Gonda.
<i>N. acuminata</i>	...	Notes on Charophytes from Gonda.
<i>N. dispersa</i>	...	
<i>N. axillaris</i>	...	
<i>N. mucronata</i>	...	British Charophyta. ²
<i>N. leptodactyla</i>	...	Journal of the Linn. Soc. Botany, Vol. xlv, September 1922.
<i>N. batrachosperma</i>	...	Br. Charophyta.
<i>N. furcata</i>	...	
<i>N. patula</i>	...	
<i>N. flagellifera</i>	...	
<i>N. hyalina</i>	...	Br. Charophyta.
<i>T. prolifera</i>	...	do.
<i>C. Wallichii</i>	...	Notes on Charophytes from Gonda.
<i>C. corallina</i>	...	
<i>C. Braunii</i>	...	Br. Charophyta; Notes on Charophytes from Gonda.

¹ Journal of the Linnean Society (Botany), vol. xlv, April 1924.

² Groves and Bullock-Webster: Ray Society.

<i>C. erythrogyna</i>	...	
<i>C. hydropitys</i>	...	
<i>C. vulgaris</i>	...	Br. Charophyta.
<i>C. contraria</i>	...	do.
<i>C. fragilis</i>	...	do.
<i>C. brachypus</i>	...	
<i>C. zeylanica</i>	...	

I have recently compiled a small fasciculus of some Saharanpur charophytes and in connection therewith a paper was jointly contributed by Mr. Groves and myself to the Journal of Botany.¹ Descriptions of two "new species" (*N. flagellifera* and *N. patula*) appear therein together with some notes on the distribution of the plants included in the fasciculus and some remarks on ecology.

Nitella mirabilis (Nordst. MS) J. Groves (Plate I.)

It will be seen that the genus *Nitella* is primarily divided into those species with branchlets uniform and in one series (Homöoclemae) and those with branchlets of varying length and nature and arranged in three series (Heteroclemae). As of the Indian species so far recorded there is only one, *N. hyalina* (which is readily distinguished from all others) falling within this latter division we may pass on to the next sub-division of the former into those with dactyls (ultimate rays of the branchlet) consisting of a single cell (Anarthrodactylae) and those consisting of two or more cells (Arthrodactylae). There are only two *Nitellas* with single-celled dactyls, *N. mirabilis* being one of them. This plant is dioecious whilst the other, *N. acuminata*, is monœcious. Identification should therefore present no difficulties as it differs to a marked degree from all others, the most peculiar feature being the clustered long-stalked reproductive organs (text-fig. 1.) The bunches of red antheridia make it very conspicuous in the water.

In Notes on Indian Charophyta this species is described as "*glæcephala*?" with the remark that the very young fertile heads of both plants appear to be enveloped in a slight mucus cloud. According to my observations the young male head is normally completely surrounded by a substantial mass of mucus. This can be made out fairly well in the accompanying plate which includes both male and female examples of this species. The female head has only a slight trace of mucus on it. Seen growing it is a delicate looking plant, usually about a foot high and of a decidedly lax habit, feeling

¹ *The Journal of Botany*, December 1927.

to the touch like a mass of filamentous algae in spite of the lime incrustation. On one occasion I came across a dwarfed form which bore no signs of any mucus.

Lime incrustation is a very common feature amongst charophytes and is generally more or less uniform or else annular in character. The authors of British Charophyta write that "many species appear to flourish most in water charged with a considerable quantity of lime, which they take up readily in the form of incrustation, not only on the exterior but beneath the cortex of the stem and branchlets. This calcareous incrustation adds greatly to the rigidity of their structure." And of the genus *Nitella* they remark that "the incrustation when present is almost always annular in character, the bands being approximately of the same width as the spaces between them. We have not met with any explanation of the cause of this phenomenon which is apparently peculiar to the genus, *Tolypella nidifica* and a few *Charae*." With reference to the last remark I may repeat here that I found in the Gonda district some *C. zeylanica* with annular incrustation.

On the question of rigidity it is worth noting that in *N. mirabilis* it almost invariably takes the form in the case of the dactyl of as many as ten narrow rings with usually a coating of lime at the exposed end (a feature often found amongst lime banded charophytes) whereas it takes quite a different form for instance in *C. Braunii* where in the branchlet the much broader rings always appear singly in the middle of the internode. The *C. Braunii* pattern would be of little use to strengthen the long slender internode of *N. mirabilis* where the binding takes the form adopted by the makers of split cane fishing rods. This kind of ring is clearly depicted in the beautiful plate of this plant in Notes on Indian Charophyta. The drawing shows this in the female: it may occur of course in the male as well.

General incrustation is confined to the corticate Charas and seems to be particularly developed in those species e.g. *C. vulgaris*, *C. contraria*, *C. zeylanica* and *C. brachypus* which ordinarily grow in masses. In such surroundings some form of strengthening would appear of special service. In the more solitary *C. fragilis* I find little if any lime except when it occurs in running water: charophytes in such a habitat tend to be heavily incrustated. It may be mentioned that the lime is not always taken up evenly. For instance I noticed in some *C. hydropitys* that the corticate segments of the branchlet as well as the stem were thickly incrustated while the ecorticate segments bore none at all.

In January 1926 I found a small pond almost completely carpeted by *C. Braunii* in a young state to the exclusion of every other

charophyte but a few very stunted plants of *N. mirabilis* in one corner. A peculiarity at once noticeable about the latter was the substitution of the usual type of lime ringing by the *C. Braunii* form, there being for each internode but one band and that too a broad one. But correlated with this was the much reduced length of the internode.

This feature appears to have no connection with protection from being eaten: for charophytes whether incrustated or not appear to be nobody's fodder, even the voracious water snails that often frequent them not fancying them as food though not despising them as an occasional site for an egg mass.

N. mirabilis occurs here fairly plentifully wherever the bottom consists of really soft mud. It is always very regular in its time of appearance, never commencing till December. It evidently needs plenty of sunshine not ordinarily obtainable till the decay of the exuberant submerged vegetation of the rainy season has cleared the way, and prefers to have plenty of room to itself.

Nitella acuminata Braun.

Though closely allied from the point of view of classification the present plant bears little resemblance to *N. mirabilis*, their similarity in both having one-celled dactyls being only revealed with the aid of the microscope. Though the two species agree in the branchlets being but once forked *N. acuminata* is of a much more substantial build and shows a greater inclination to spread. It is monoecious. A character that readily indicates this species "in the field" is the tufted form of the young branches. (Text-fig. 2). It is not likely to be confused with any other charophyte. The plant's particular feature from which it derives its specific name is the very long sharp point to the dactyl. (Text-fig. 2 a).

The species has a wide range in the tropics, more or less encircling the globe, and has been recorded from various parts of India. It grows very freely in masses during the rains.

Nitella dispersa Braun. (Plate II).

Here we pass to that large subdivision of the Nitellas whose dactyls consist of two or more cells. Seen growing the present species is not unlike a tall form of *N. mucronata* though more forked and with more rays and normally not fruiting at the first furcation. It is however readily distinguished from it by its dioecious character. There are only (apart from *N. mirabilis* above mentioned) two other dioecious Nitellas recorded as yet from India, the material in both cases being so scanty that neither has yet been assigned a name. They are nos. 4 and 15 in Notes on Indian Charophyte.

My first specimens of this plant gathered on November 8th 1923 proved rather a problem even under expert examination. Prior to my finding this species the only records were Braun's from the Concan and Assam. The special features of Braun's plant are the two-celled dactyls, ultimate cells conical, dioecious, branchlets up to four times forked, dactyls three to five of unequal length and the primary rays elongated.

The peculiar feature of my plant is the presence of curious long allantoid (sausage shaped) ultimate cells in many of the dactyls while in others there is the usual conical one. (Text-fig. 3). This ray with the long ultimate cell is often the principal one *i.e.*, the axial one. Nodes may however for instance occur in which a ray proceeds to furcate, while the other lateral rays are very elongated and have the exceptional allantoid apical cell. This long ultimate cell does not occur unless the penultimate cell is also elongated, the former comprising as much as half the ray, though there also occur very long dactyls with the ultimate cell of the usual short conical form.

On the first occasion I gathered this plant the strange elongated cylindrical cells were fairly plentiful which led to the suspicion that this might be something different from Braun's plant where the occurrence of this cell is not mentioned. In a subsequent gathering on 2nd December there was a fair amount of the unusual cell on the male but scarcely any on the female. The irregular occurrence of this cell taken in conjunction with the fact that it otherwise agrees fairly well with *N. dispersa*—for instance this and the Assam plant are alike in the oospore membrane having imperfect reticulation with a tendency towards a line across the intervals—eventually led Mr. Groves to conclude that my plant belonged to this species and that evidently in the specimens of *N. dispersa* seen by Braun it did not occur or he would certainly have mentioned the fact. In some further gatherings of this plant in November 1926 there appeared to be two forms, one rather lax and the other of stronger build. The quantities of antheridia all over the extremities somewhat resembled in miniature a lot of little oranges growing on a bush. Some pieces I gathered on one occasion I thought at the time to be covered with ripe oospores but on examination they proved to be quantities of *Stentor niger*!

On 8th Jan. 1934 I came across a still more puzzling plant (Plate II) in the same place as I had found the *N. dispersa*. In fact my special object in visiting this pond was to obtain some more material of my unusual find. Thanks to several days' recent rain which is always liable to occur in these parts at this season and is known as the Xmas rains I found as I anticipated a much enlarged pond and the water like pea soup. The only thing to do was to resort

to the grapple and with this I managed to haul in a large mass of *Nitellas* mixed up with a lot of *C. Braunii*. This method is not one to be recommended if specimens can be secured in any other way as the task of disentangling is tedious and rather disappointing as the material is bound to suffer in the process. Sorting it out proved to be more than usually difficult in the present case: for in addition to much *N. dispersa* above mentioned I also noticed a species that consisted of a mass of tufts which acted like so many burs and interlocked in the most exasperating manner. The plate gives a very fair idea of the general appearance of the plant.

The main features are as follows: dioecious, dactyls all two-celled, ultimate cell normally conical, generally three furcations, the first and second internodes being very long comparatively and the third very short *i.e.* much shorter than the dactyls so that the plant has the appearance of a lot of little tufts at the end of long branchlet internodes (Text-fig. 4). Incidentally the dense tufts as so often the case with *Nitellas* were a mass of dirty particles and it was not very easy at first to make out the third furcation. The enveloping cells of the oogonium seem to be rather large compared with the oospore while the coronula looks small. The reproductive organs are numerous and crowded together at the third furcation.

Mr. Groves found this plant had much in common with my *N. dispersa* except for the shortening of the upper rays giving it a tufted appearance and the oospores being shorter: the oospore membrane of both is similar. His final verdict is that this plant must be referred to *N. dispersa* in spite of the difference in vegetative growth. Occasionally an allantoid cell is to be found in the tufted form as well though neither this ultimate cell nor the dactyl is nearly as long as is found in the other form. "The capitate form," he writes, "collected on 8th Jan. looks very different but capitate forms occur in many *Nitellas* and our common British species vary so much in this respect that the extremes look quite unlike the same species." It is curious that these two forms should have flourished together.

Nitella axillaris Braun. (Plate III).

This very peculiar species I did not meet with till the rains of 1926 when I devoted considerably more attention to charophytes than in previous wet seasons. Its chief characteristic lies in its reproductive organs being entirely borne on special little much crowded axillary branchlets. Once examined it cannot be confused with anything else though its close superficial similarity in a young state to *N. acuminata* in the midst of masses of which the plant occurred very sparingly deceived me somewhat at first.

It is very near *N. translucens* which occurs in England but in my plant the little heads are always axillary. These fruiting heads are as many as five at a whorl. The branchlets at first sight look single-celled but the lens discloses a terminal furcation into two or three minute sharp-pointed 2 celled dactyls.

This is the only Indian record of this plant. It has not been mentioned from the mainland of Asia before.

In the two ponds where this species occurred it was always closely associated with *N. acuminata*. I noticed it as early as Aug. 20th : they both disappeared as soon as the rains ceased.

Nitella mucronata Miquel.

"The Nitellas," writes Mr. Goves, "present many difficulties in classification. In such a plastic genus it is difficult to see what characters can be trusted to discriminate species." Now *N. mucronata* is a sort of miscellaneous department: plants that cannot be got to fit in elsewhere and yet do not possess sufficiently pronounced constant differences of their own to warrant the creation of a new species are apt to find a home here. "In this all too large a category," writes the same authority, "I have had to place a good number of doubtful plants from various parts of the world."

In spite of all this the commonest and typical form is not difficult to distinguish. It grows in a short roundish clump and for a *Nitella* is quite stiff. If all charophytes behaved as this does making satisfactory dry mounts would present few difficulties: after the excess water has drained off the branchlets soon spring up again and tend to recover their natural position. The furcation of the branchlet is of a comparatively simple and regular character. The primary ray is never more than half the length of the whole branchlet: usually there are only two forks and the rays at the second forking but two or three, reproductive organs occurring at all the nodes.

Under the microscope the dactyls will be seen to consist generally of two cells but occasionally three while the narrow end-cell is perched micro-like on the rounded lower one, this peculiarity giving the plant its specific name (Text-fig. 5). This form is common in shallow open water in the earlier portion of the cold weather and prefers nice soft mud.

I have found one or two other forms that provisionally have to be placed under this species but although they differ considerably from the normal form descriptions would not I think serve any useful purpose.

Nitella leptodactyla J. Groves.

My hunting in the cold weather of 1924-25 was seriously interfered with by the extensive floods, unprecedented locally in the memory of man, that occurred at the end of September. This gave rise to a dense growth of coarse grass round the ponds and when at last they appeared again as such after being lost for weeks in a watery waste the muddy zone usually made accessible by evaporation in the cold weather instead of being rich in charophytes was often a tangled mass of floating grass ends. I was rewarded however on 10th November by a prize in the shape of an extremely slender *Nitella* with very bushy whorls due to the numerous branchlets and their many furcations. It proved to be *N. leptodactyla* hitherto only recorded from Ceylon and first described by Mr. Groves in his paper on Mr Blow's collections from that area. The plate accompanying that paper really makes further description unnecessary. Of this plant Mr. Groves writes that he thinks it quite the daintiest he has yet handled, the ultimate rays being only 25 to 30 μ in diameter. He makes it out to be mucus headed though only apparent in quite the youngest heads. I had noted down in my diary "no signs of mucus" so it is evidently not conspicuous. He is not however disposed to set much store by this mucous character to distinguish species as it is not constant. A striking example of this is *N. batrachosperma*: the European plant sometimes has the mucus so pronounced as to have given rise to its specific name whereas my Gonda plant as also my Saharanpur one had none.

The occurrence of this plant well illustrates the very capricious appearance of charophytes. The particular pond in which I found it is quite small and the open parts can be fairly thoroughly searched in under half an hour. As it received considerable attention from me during this period in 1923 it is improbable that I should have overlooked this species had it been present then. Stress is laid on this characteristic in British Charophyta where an instance is cited of a collector who would not give away the locality of a rare species he had found. The authors remark in that connection that "had he been aware of the true nature of the *Nitellas*—the practical impossibility on the one hand of ensuring their permanent growth, and on the other of effecting their extermination—he would scarcely have maintained his silence." I have not succeeded in finding this plant again. For two succeeding years the locality was under crops.

¹ On Charophyta collected by Mr. Thomas Bates B'ow, F.L.S., in Ceylon, *Journl Linn. Soc., Botany.* vol. xlvii, September 1922.

Nitella batrachosperma Braun.

The minute size of this plant, the smallest of all the Indian charophytes, will help to distinguish it: but for this very reason it is probably often overlooked. There are generally eight branchlets to the whorl: the dactyls are very long and narrow (Text-fig. 6); usually twice forked and with gametangia generally at the first furcation only. The oospore ridges have conspicuously broad flanges.

Of Indian plants it most nearly resembles *N. tenuissima* of which there is but a single record of *var. byssoides* by Braun a hundred years ago from the Coromandel coast. So far as my experience goes it occurs very sparingly here. I have found it on but two occasions only. Happening early in December 1924 to examine a little roadside pool, I came across this species though taking it at first to be *N. mucronata*. It was a distinctly larger plant than the Gonda one reaching 10 cm. in height. My next meeting with it a year later was very unexpected. I was engaged in searching a reach of the river Damola, a fairly rapid shallow stream though frequent bends lead to the formation of many more or less stagnant pools. This species is particularly partial to extremely fine mud such as would not occur in a stream. The plant had however found a very efficient substitute in a mass of decaying filamentous algae, a softer bed than which is hardly possible. The specimens were very minute like the Gonda ones which were also found in very shallow water. It is worth noting that in Ireland it occurs in four to six feet of water. My present record and that from Gonda are the only two so far from India.

Nitella furcata Agardh (= *N. Roxburghii* Braun). (Plate IV).

This species belongs to a group of four in which some at any rate of the dactyls are conspicuously short and are hence known as the Brachydactylae. These dactyls are divergent and generally arise from a sterile node. (Text-fig. 7 a). The distinguishing feature of the present species is the extraordinarily tall coronula due to the cells of the upper layer being prolonged into sharpish points. This upper layer though normally straight sometimes adopts a very irregular shape (Text-fig. 7 b). The coronula often presents a somewhat striking resemblance on a microscopic scale to the persistent projecting calyx of the pomegranate fruit. To make out this peculiar feature in the coronula requires some care but once seen there is no mistaking it.

I had at one time contemplated including another of the four, *N. microcarpa*, in my Saharanpur list but on a further examination of the very limited material available I hardly felt this was justified. In

both these species the oogonia are clustered. The coronula of *N. microcarpa* is normal but between the two there are regular gradations.

Happening to devote much more time to charophyte hunting in the rains of 1926 than in previous years I found *N. furcata* to be quite a plentiful species at that season. Earlier specimens of it collected at the beginning of the cold weather had been in poor condition. Indian records of it are very meagre: it occurs in Ceylon and a few other scattered places such as the Coromandel coast and Pegu.

Nitella patula Groves and Allen.

On 12th October 1926 I chanced during my rounds to revisit a small pond and nearly passed it by as unprofitable as there was such a dense growth of rushes round the edge. Luckily however I was prompted to have a look at the small patch of open water in the centre of the pond and to my great surprise found a mass of a beautiful *Nitella* in splendid condition in nice deep water. For the time being this had to be relegated to *N. mucronata* sens. lat. but closer examination has led to its being pronounced worthy of specific rank: it is described in the Journal of Botany as mentioned above. It resembles *N. furcata* in habit. Its most marked characteristics are the larger number of furcations and rays and the oogonia being solitary: the oospore is light brown.

Nitella flagellifera Groves and Allen. (Plate IV).

This has also been recently described in the Journal of Botany. On 24th October 1926 in a pond adjoining that where *N. patula* occurred I found a plant that I realized at once was different from anything I had gathered before. It was after the style of a stiff *N. mucronata* but its fruiting was most peculiar. At most stem whorls there was produced at the first two furcations of the branchlets a separate little shoot (flagellum) bearing many reproductive organs: hence its specific name. The illustration shows the rather characteristic shape of the branchlets.

Nitella hyalina Agardh. (Plate V).

This pretty little species is the only Indian representative of the section *Heteroclemae*. The branchlets in each whorl are in three series, the upper and lower being short and alike, the middle one much longer and more forked. The existence of two distinct kinds of branchlet is very easily made out and renders this plant a simple one to identify. Seen growing it is also readily recognised by its small roundish whorls separated by very long internodes and by its generally having such a lot of mucus on it as to give it quite a jelly-like feel.

I found a couple of little tufts of this species on 18th October 1923: there was rather less mucus than usual. This is the only occasion I have come across this plant at Saharanpur which is rather surprising seeing that it was particularly common at Gonda and has a wide distribution in India and the world generally. A visit to the spot about the same time another year disclosed no signs of it.

Tolypella prolifera Leonh. (Plate V).

Judging from my own brief experience the only member of this genus likely to be found in this part of India is the present one. *Tolypella* is distinguished from *Nitella* by the antheridia being lateral instead of terminal but a glance at the accompanying plate will show that the general appearance of the two is very different. The most conspicuous feature of *T. prolifera* is the presence of long sterile simple, i.e., nonfurcating, branchlets. The only charophyte for which I have on one occasion mistaken it in its natural surroundings was a form of *C. contraria* in which there occurred at the lower nodes a whorl of entirely ecorticate sterile branchlets that thus produced a distinct superficial similarity between the two, especially as they were growing all mixed together. The ultimate cells of the present species being conical is a character that definitely distinguishes it at once from the other two *Tolypellas* recorded from India. (Text-fig 8.)

T. prolifera like many other charophytes is remarkably constant in its time of appearance. It commences with December and flourishes for rather over a couple of months: it occurs very sparingly. Gonda was its first Indian record: I hear that it occurs also in South India.

Chara Wallichii Braun.

The genus *Chara* to which we now pass is primarily divided into those with a single row of stipulodes (Haplostephanae) and those with a double row (Diplostephanae). *C. Wallichii* belongs to a further sub-division of the former comprising three ecorticate species that are all found here, being easily distinguished from the other two by its dioecious character. It should be added however that in *C. Wallichii* as well as in *C. corallina* the stipulodes are usually much obscured by the gametangia which in both these species are produced freely at the base of the whorl.

In life it is a large robust angular-looking plant, rather spiky in appearance and very brittle (Text-fig. 9.). The antheridia are particularly large, much exceeding in length the oospores. It is fairly frequently met with in this area and grown singly in clumps. It is probably a good deal commoner in the Gangetic Plain than the meagre records indicate. I have recently had specimens of it from Benares and found it at Gonda and Lucknow.

Chara corallina Willd. (Plate VI).

Though very different in general appearance this plant has not a great number of characters distinguishing it from *C. Braunii*. It produces gametangia at the base of the whorls as well as at the branchlet nodes while *C. Braunii* has none at the former (Text-fig. 10). The oospore is far larger than that of *C. Braunii*. The branchlet cells of *C. corallina* tend to be very swollen and the plant is very brittle while the other species is distinctly flexible and slender. *C. corallina* is usually a very robust plant often growing in largish clumps by itself. When growing amongst fairly thick vegetation the stem internodes are often much elongated and the whole plant as tall as two feet whilst the gametangia are generally borne on rather crowded branches near the water surface. Lime incrustation is usually annular in character. The branchlets though closing together at the tips in the young state project conspicuously when older and may reach the great length of over 8 cm. whereas those of *C. Braunii* are usually very regular and 2 to 3 cm. in length. These exceptionally long branchlets are sterile.

C. corallina is fairly common and may be found throughout the cold weather being at its best, like *C. Braunii*, in January and February. It is widely distributed in India.

Chara Braunii Gmel.

This is quite the commonest charophyte here. It may be found freely in almost any pond one visits in the latter half of the cold weather and struggles on right through the hot season as well. Though I did not find this plant common at Gonda, failing in fact to run across it my second season there, it has a wide range in India even reaching 6,000 feet in the Western Himalayas and is found in all the continents of the world.

One noteworthy feature is the extremely short terminal segment of the branchlet (Text fig. 11a). This segment is only about the same length as the two or three developed bract cells and consequently presents much the same appearance on a larger scale as the tip of a brachydactylous *Nitella* branchlet. Its synonym of *coronata* is due to this peculiarity. It not infrequently grows in huge patches.

Chara erythrogyna Griffith. (Plate VI).

In general appearance this plant bears little resemblance to the three Charas already mentioned. It looks more like a small form of *C. zeylanica*. It will be seen from the illustration that the whorls are far apart and the branchlets comparatively short and stiff. Though belonging also to the haplostephanous sub-division it differs from the first three in the stem having a cortex though the branchlets are entirely ecorticate.

There are only two other Indian species in which these two features are combined. *C. erythrogyna* differs however markedly from them in the peculiar fact that as a rule at the branchlet node either oogonia or antheridia are present but not both whereas in the other two both may occur together in the ordinary way. The segregation of the male and female reproductive organs seems to be carried even further than this: for I often found a whole branchlet and not merely a node to be either male or female.

Griffith who first named the plant states that this plant is remarkable for the red colour of the females. The colour of the oogonia is a fine deep reddish brown. The antheridia being bright red as is not uncommon amongst charophytes the combination of the two produces a very pleasing effect.

This species has a whorl of from 13 to 16 branchlets: the segments vary from six to eight. In my plant I have not noticed more than 13 branchlets or six segments. The main stem is particularly tough which is fortunate as disentangling it for herbarium purposes is difficult.

Braun distinguished another species as *C. Thwaitesii* that hails from Ceylon. The alleged characteristics of it are the short stipulodes, the branchlets being ten to twelve in a whorl and the segments 4 to 5. Of these three points much the most noticeable is the first but Mr. Groves has little opinion of this character as it is extremely variable in this section: *vide* for example his remarks under *C. flaccida* in his paper on Mr. Blow's collections of charophytes in Ceylon that "there is often considerable difference in the length of the stipulodes even on the same plant." He is of opinion therefore that the Ceylon plant is probably a variety of *C. erythrogyna*. In Braun's "Fragmente" *C. erythrogyna* appears under the name of *C. Griffithii*.

The recorded distribution of this species is very meagre *viz.* from the Gangetic plain only except for the Ceylon variety. It is not mentioned however in the Ceylon paper which was confined to two collections in 1895 and 1898 by Mr. Blow who apparently did not come across the plant. Curiously enough one of the few previous records from the Gangetic plain is the Saharanpur Botanic Garden. In these famous gardens however the only spot that was once probably a small pond does not appear to hold water nowadays.

***Chara hydropitys* Reichb.**

This species is closely allied to the last and not at all unlike it in appearance though considerably smaller. In both the stem is corticate: in the present species the branchlets are mainly corticate but the lowest segment is always ecorticate.

I found this species on one occasion only viz. September, 1926 : it was in evidence for a very short time as it was growing in shallow water at the edge of a pond that rapidly dwindled.

There are few Indian records of this species ; it has been found in Bengal and Ceylon and I collected it at Gonda. I have also received specimens from Coimbatore.

Chara vulgaris L. (Plate II).

This plant is recorded from all over India and has in fact a world-wide range. It is somewhat surprising that I did not find it at Gonda. It is a species that revels in variations though the authors of British Charophyta remark with reference to Dr. Migula's elaborate enumeration of 70 European varieties that "it is difficult to see that any useful end is served by the attempt to make minute distinctions between plants that are evidently mere states." The causes of these variations moreover are not apparent as plants are found under similar conditions in adjacent spots and yet showing slight differences. Four of the most noteworthy British varieties are figured in plate XXIX Br. Charophyta, vol. II.

Much the commonest form in Saharanpur (Plate II) evidently tends towards var. *longibracteata*, the particularly lengthy anterior bracteoles and bract cells showing up quite clearly. It is noteworthy that these bract cells should be very long while the stipulodes and spine cells are not correspondingly developed, which is contrary to the usual practice amongst charophytes. With reference to my plate I should mention that the contortions represent the plant's natural state, a feature quite in keeping with its general wayward habits.

It grows in dense masses as a rule. The strong odour it emits makes its old synonym of "*foetida*" particularly appropriate.

As I mentioned in my Gonda paper the species most nearly resembling *C. vulgaris* is *C. contraria*. They both belong to the diplostephanous sub-division of the genus, the most readily distinguishable difference between the two being that in the former the spines seem to lie in furrows i.e. the secondary series more prominent than the primary (aulacanthous) whereas in *C. contraria* the exact reverse is the case, the primary spine bearing series being more prominent than the secondary (tylacanthous). A comparison of plates XXVIII and XXXIII Br. Ch. vol. II will make this point abundantly clear, though in practice the irregularities of the cortex often necessitate the examination of a young shoot before recognition is at all certain. The series that is the larger in girth when viewed in cross section will naturally be the broader in surface view.

There is also a tendency with *C. vulgaris* for the two rows of stipulodes to be neat and equal in size whereas in *C. contraria* the lower is often irregular and smaller than the upper. So far as I have noticed the apex of the branchlet of *C. contraria* has always a few ecorticate segments this tendency being less pronounced in *C. vulgaris*. The ripe oospores too of *C. contraria* are black while those of *C. vulgaris* are usually dark brown. They may further be distinguished by the marking on the oospore membrane. The decoration in *C. contraria* is known as granulate, the granules being all contiguous while in *C. vulgaris* it consists of separate little tubercles.

Chara contraria Kutz.

This plant also tends to vary somewhat. In general appearance it is rather neater than *C. vulgaris* and often has a slightly bluish-green tinge about it. I have referred above to a form with ecorticate lower branchlets.

As at Gonda I found this species a distinctly cold weather type : it does not seem to germinate before the middle of November. It is a common plant in Indian waters and is found in all five continents.

Chara fragilis Desv. (Plate I).

Though not unlike in general appearance the other two triplostichous species, *C. brachypus* and *C. zeylanica*, it differs in being of a solitary disposition though often growing in clumps. The branchlets tend to be longer and though not spreading out much near the node generally develop graceful curves towards the free ends. There are usually only three or at most four fertile nodes to the branchlet, these being situated at the base of it and thus leaving a long bare upper portion. The stipulodes and spine-cells are always very inconspicuous, even rudimentary, and blunt in outline. There is little lime incrustation as a rule.

Though not occurring anywhere abundantly it is often common locally and has a world-wide distribution.

I should add that Prof. N. K. Tiwary of the Benares Hindu University recently sent me a plant he gathered at Benares in 1924 that proves to be *C. delicatula* Agardh. This is the first record of it in India. It closely resembles *C. fragilis* but is mainly distinguished by the primary cortical cells being larger than the secondary, whereas in *C. fragilis* they are both of the same size and by the stipulode cells being more or less elongated instead of rudimentary as in *C. fragilis* and the spine-cells being papilliform instead of hardly visible (*vide* plates XLIII and XLIV Br. Ch., vol. II).

Chara brachypus Braun.

A typical tropical species that grows in dense masses in the rains and early cold weather. It is usually heavily incrustated, a fact which doubtless accounts for its exceedingly brittle nature. It may be readily distinguished by the lowest branchlet segment being very short and incidentally colourless or nearly so (Text fig. 12 a). This very pale colour may I think be due to this segment apparently not taking up lime, a feature shared by the coronula amongst charophytes, this latter part being consequently never found in the fossil state. The stipulodes being elongated and both they and the spine cells being acute afford a marked contrast with *C. fragilis*. It seems partial to a firm soil: I have never found it growing in soft mud.

Chara zeylanica Willd.

This is a rather variable species and flourishes at the end of the rains and grows in masses. As soon as ever the cold weather sets in it dies down altogether. Though after the style of *C. brachypus* it is very easily distinguished under the microscope by the lowest branchlet segment being ecorticate (Text fig. 13). This segment is usually much shorter than the others but I found one form where it was as long as the other segments. *C. hydrophytes* also has the peculiarity of the lowest branchlet segment being without any cortex but this latter plant is otherwise quite different and belongs to the haplostephanous sub-division of the genus. *C. zeylanica* is common here and widely distributed in India.

This district may be considered to have a very rich charophyte flora. In the cold weather hardly a pond that is free from disturbance by man and beast will fail to produce a few species. On one occasion a tiny roadside patch of water not thirty yards across that would normally dry up early in the cold weather to my surprise yielded no less than seven different species. My list of 22 local species amounts to just half the total so far recorded from India.

The commonest species are *N. mirabilis*, *N. acuminata*, *N. furcata*, *N. mucronata*, *C. Wallichii*, *C. Braunii*, *C. corallina*, *C. erythrogyna*, *C. vulgaris*, *C. contraria* and *C. fragilis*. The list includes two new species and one new record for India.

A comparison with my Gonda list amounting to sixteen shows the addition here of *N. dispersa*, *N. axillaris*, *N. furcata*, *N. leptodactyla* and the two new Nitellas, *C. erythrogyna* and *C. vulgaris* but the absence of *Lychnothamnus barbatus* and *C. gymnophytes*, though the former was abundant there. Of two of the species common to both districts *C. Braunii* was scarce at Gonda but the commonest and most wide-spread here while *N. hyalina* so common at Gonda was as

already mentioned only met with on one occasion here. The periods during which I found the different species to flourish is shown in the accompanying chart. None commence after January though ten of my list I have not seen appear before November. Few survive far into the hot weather. The periods agree pretty closely with my observations at Gonda with regard to the species common to both areas.

Chart showing the periods during which the different species were found to flourish.

NAME.	June	July	August	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
<i>N. mirabilis</i>	...											
<i>N. acuminata</i>	...											
<i>N. dispersa</i>	...											
<i>N. axillaris</i>	...											
<i>N. mucronata</i>	...											
<i>N. leptodactyla</i>	...											
<i>N. batrachosperma</i>	...											
<i>N. furcata</i>	...											
<i>N. patula</i>	...											
<i>N. flagellifera</i>	...											
<i>N. hyalina</i>	...											
<i>T. prolifera</i>	...											
<i>O. Wallachii</i>	...											
<i>O. corallina</i>	...											
<i>O. Braunii</i>	...											
<i>O. erythrogyna</i>	...											
<i>O. hydrophytes</i>	...											
<i>O. vulgaris</i>	...											
<i>O. contraria</i>	...											
<i>O. fragilis</i>	...											
<i>O. brachypus</i>	...											
<i>O. zeylanica</i>	...											

Explanation of Plates

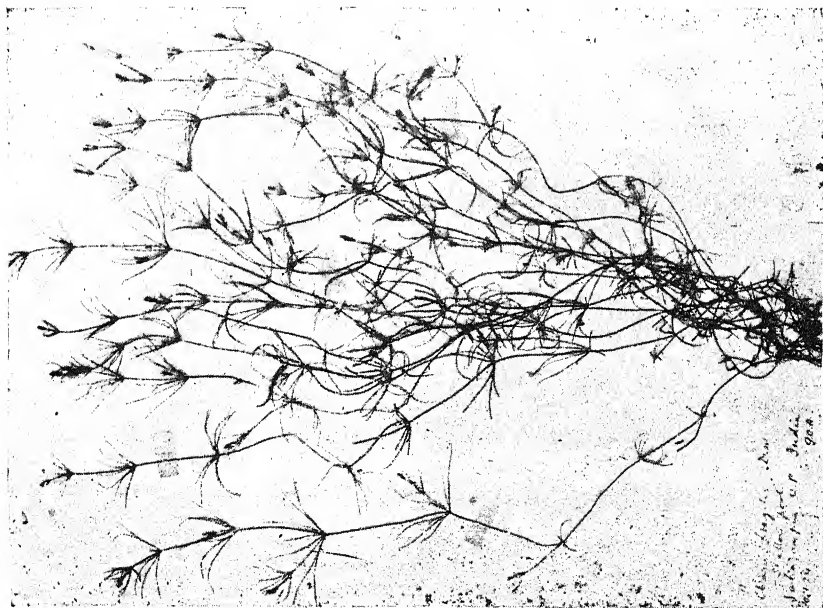
I. *N. mirabilis*.—Showing on the left the male plant with antheridia in masses of mucus and on the right the female plant (about $\frac{2}{3}$ natural size).

O. fragilis.—Rather less than $\frac{2}{3}$ natural size.

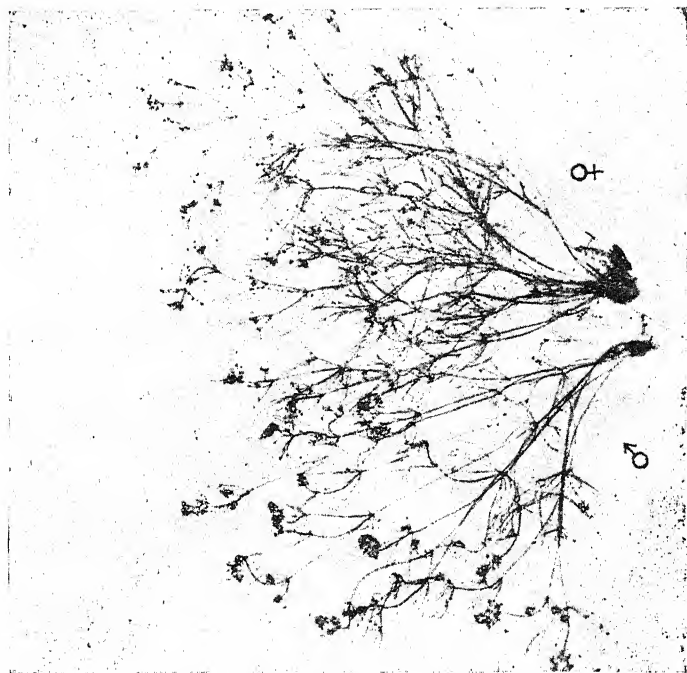
II. *N. dispersa*.—Capitate form. (about $\frac{2}{3}$ natural size).

O. vulgaris.—Rather less than $\frac{2}{3}$ natural size.

III. *N. axillaris*.—(a) Whole plant rather less than half natural size. (b) Enlarged portion about double natural size.



C. fragilis.

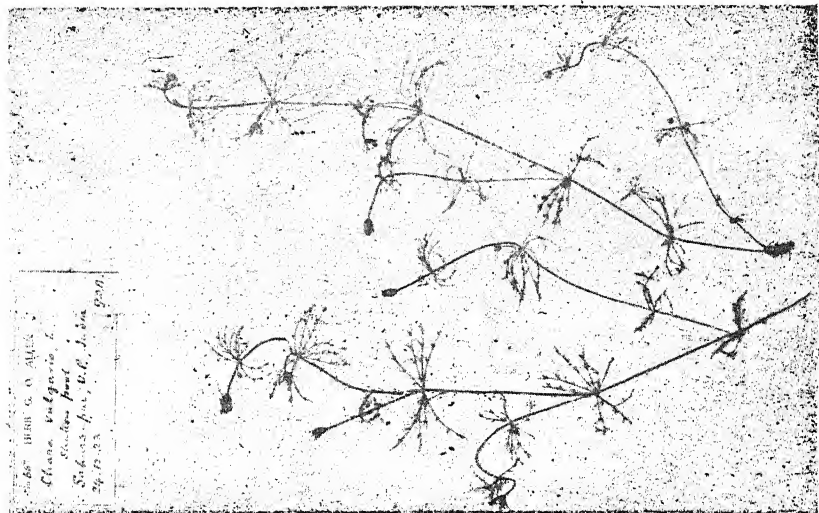


N. mirabilis.



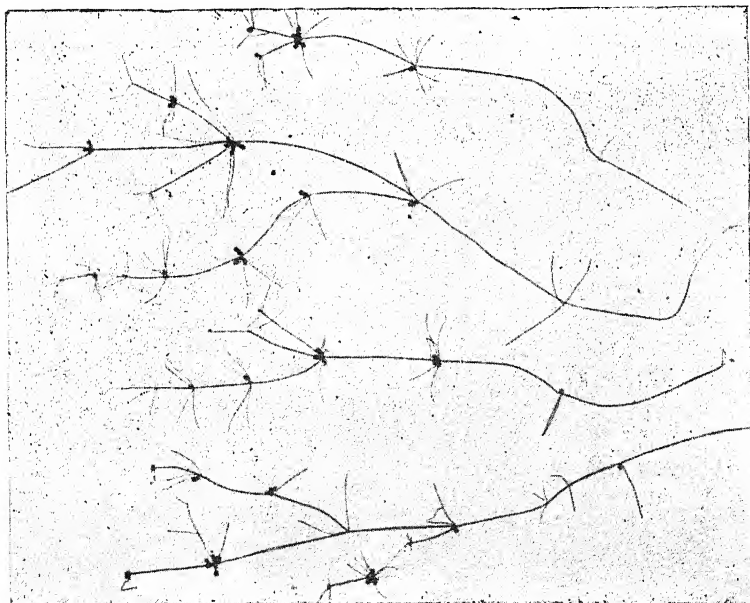


N. dispersa.



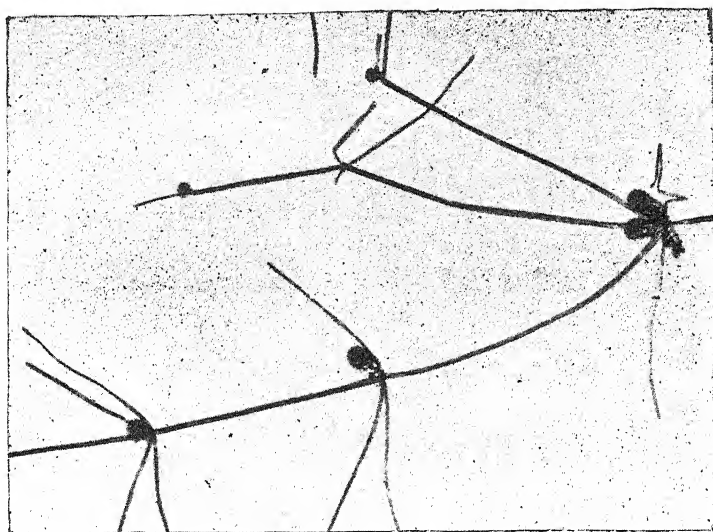
C. vulgaris.



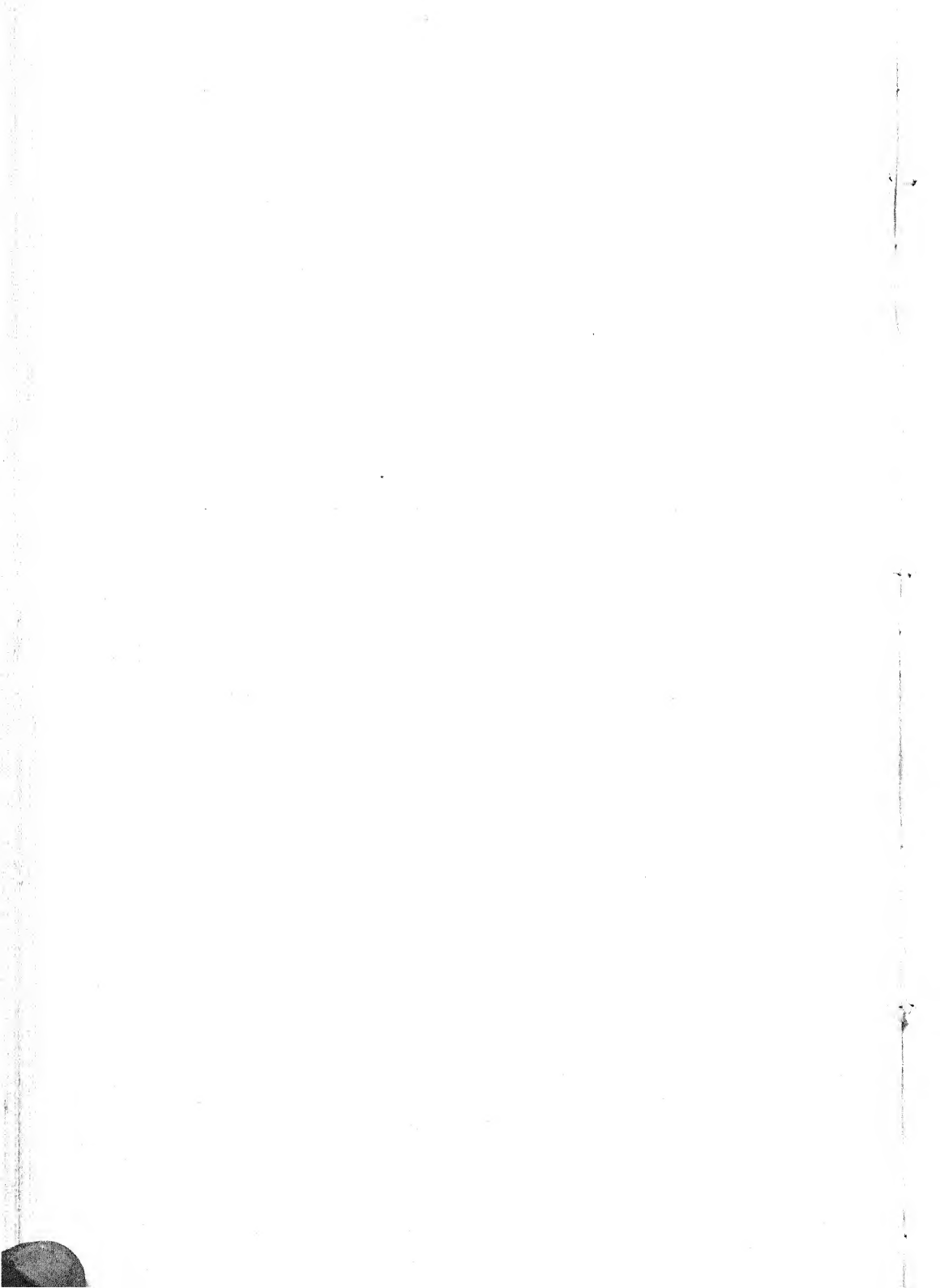


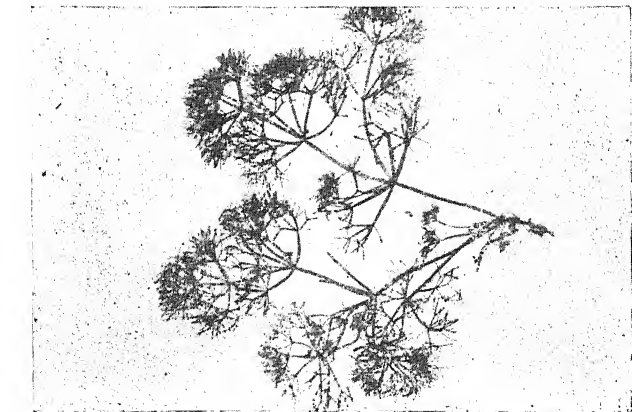
a

N. axillaris.
PLATE III.



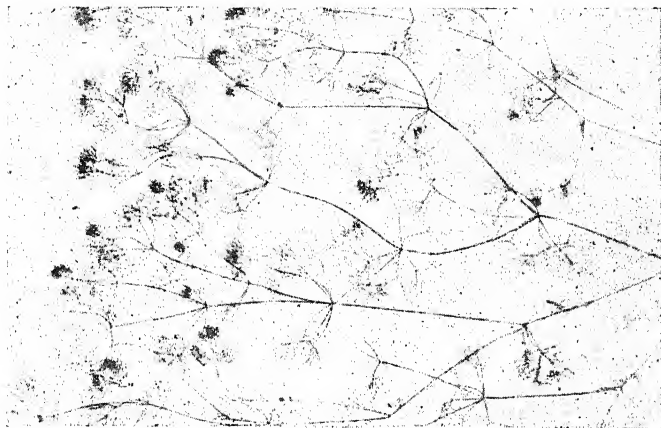
b





a

N. furcata.

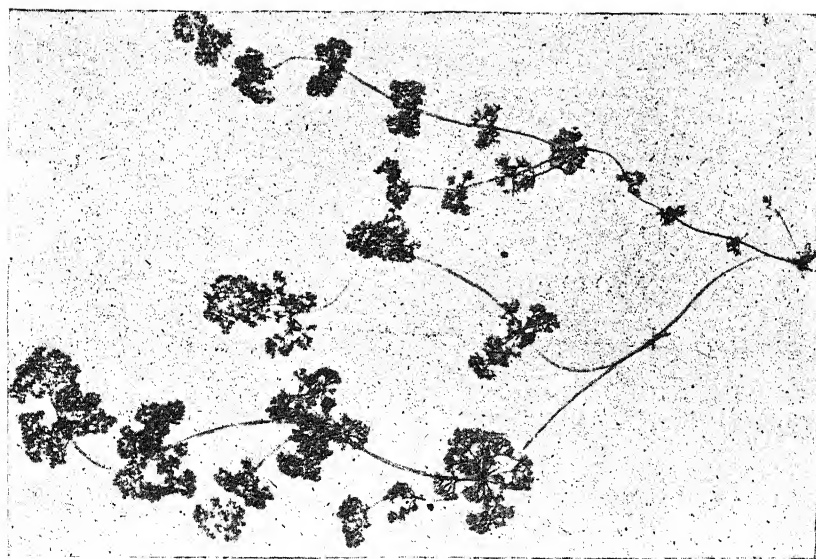


b

PLATE IV.



N. flagellifera.



N. hyalina.



T. prolifera.



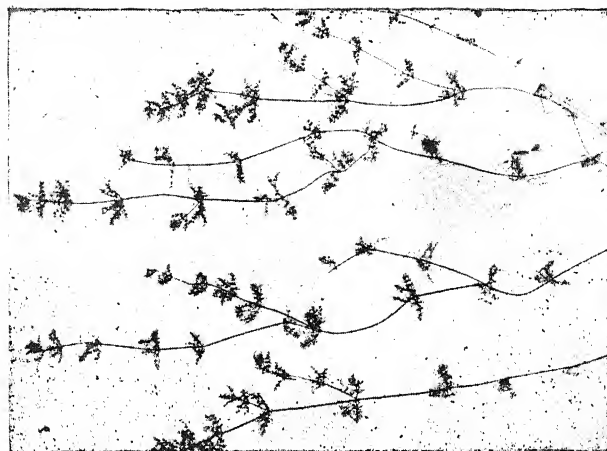


a



b

C. corallina.



C. erythrogyra.

IV. *N. furcata*.—A well grown plant in a young state. The smaller portion represents an old plant from shallow water. Both about $\frac{1}{2}$ natural size.

N. flagellifera.—About $\frac{1}{2}$ natural size.

V. *N. hyalina*.—About $\frac{1}{2}$ natural size.

T. prolifera.—Rather less than $\frac{2}{3}$ natural size.

VI. *C. corallina*.—(a) The whole plant represents a well grown specimen; about $\frac{1}{2}$ natural size.

(b) Enlarged portion (about natural size) showing the swollen branchlet cells; in a young state they close over at the tips.

C. erythrogyna.—About $\frac{1}{2}$ natural size.

Explanation of text-figures 1—13.

Fig. 1. *N. mirabilis*.—Cluster of ripe oogonia.

Fig. 2. *N. acuminata*.—(a) Apices of dactyls.
(b) Terminal whorl.

Fig. 3. *N. dispersa*.—Allantoid ultimate cells of dactyls.

Fig. 4. *N. dispersa*.—(a, b.) Somewhat elongated ultimate cell of dactyl.

(c) Normal ultimate cell of dactyl.

(d) Portion of branchlet showing secondary tertiary and quaternary rays.

Fig. 5. *N. mucronata*.—(a) Typical apex of dactyl.

(b) Three-celled dactyl.

Fig. 6. *N. batrachosperma*.—Apices of dactyls.

Fig. 7. *N. furcata*.—(a) Apices of branchlets.

(b) Oogonia showing elongated corona.

Fig. 8. *T. prolifera*.—Fruiting branchlet.

Fig. 9. *C. Wallichii*.—Apex of branchlet.

Fig. 10. *C. corallina*.—(a) Apices of dactyls.

(b) Stem node with branchlets.

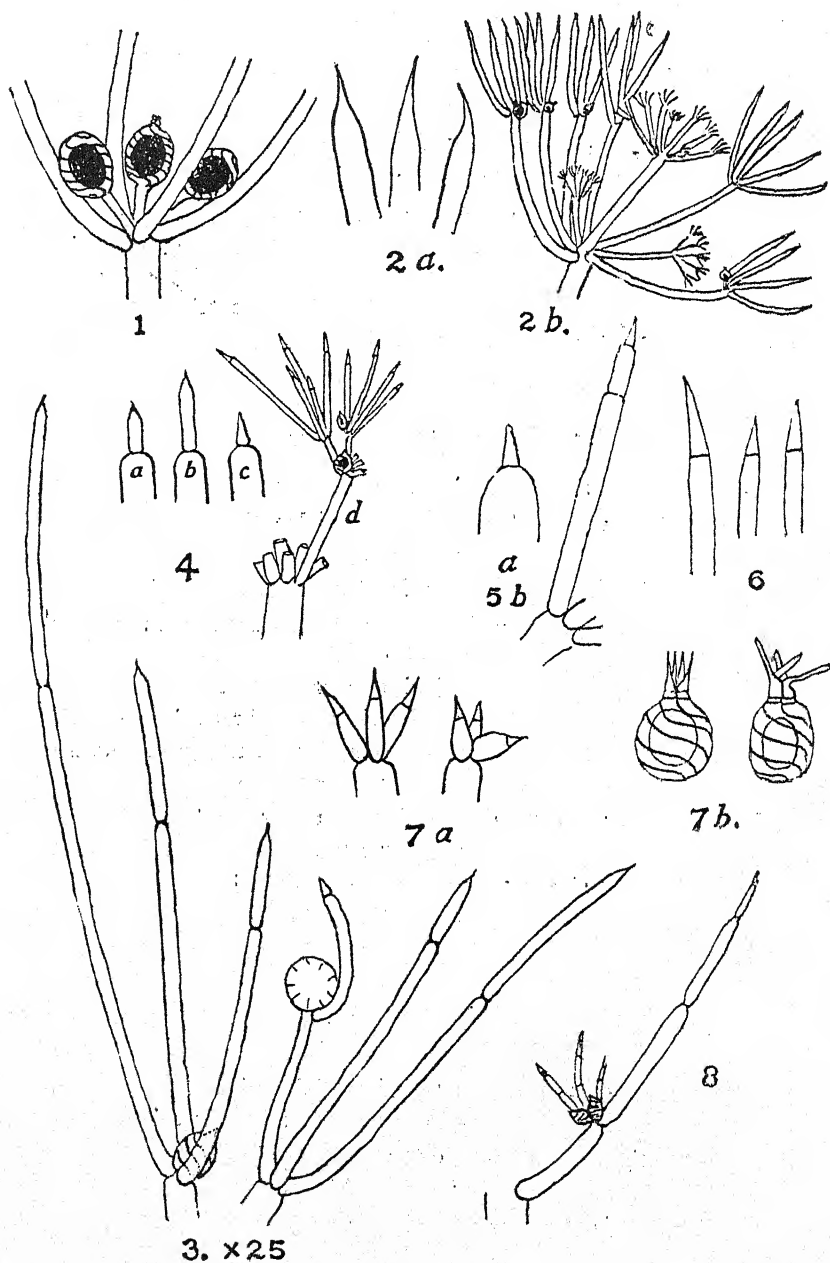
Fig. 11. *C. Braunii*.—(a) Apex of branchlet.

(b) Branchlet whorl.

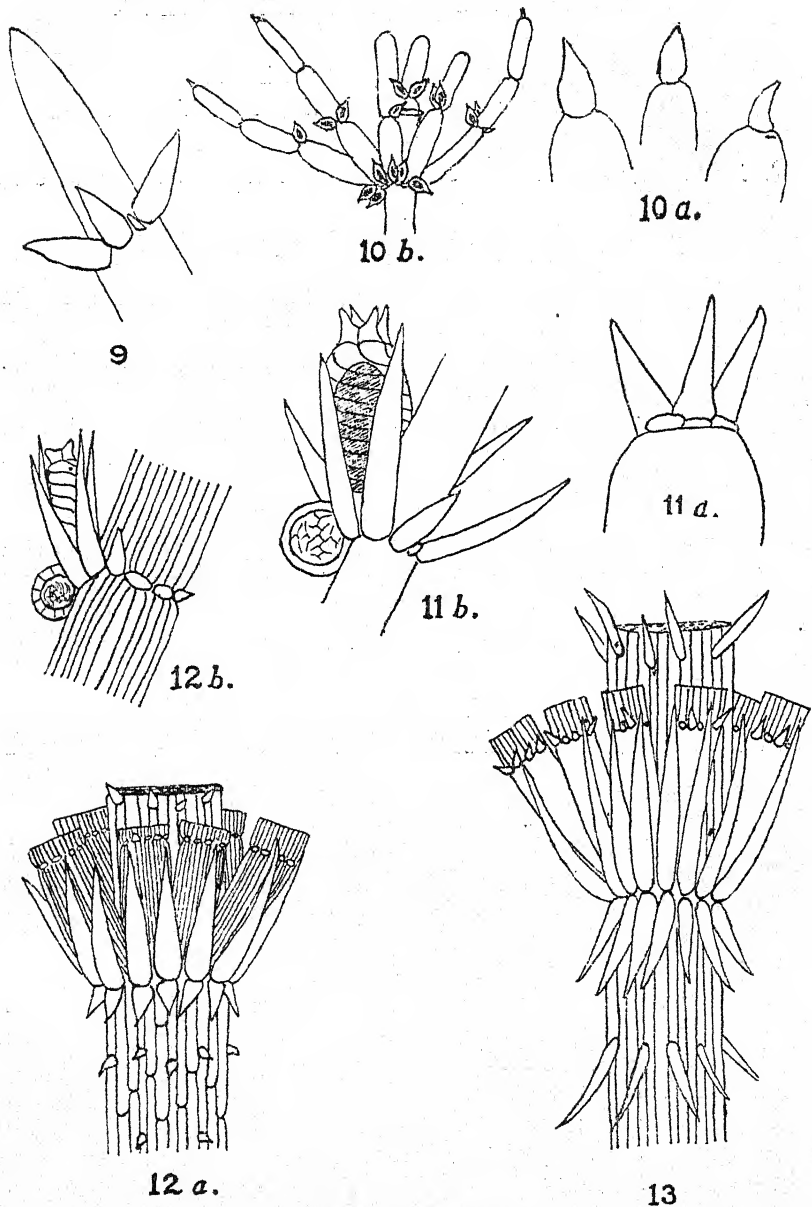
Fig. 12. *C. brachypus*.—(a) Stem node.

(b) Branchlet node.

Fig. 13. *C. zeylanica*.—Stem node.



Text-Figs 1-8.



Text-Figs 9-13.

THE FLORA OF THE INDUS DELTA

BY

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PART V.

(Continued from p. 43, Vol. VII, No. 1).

IV. A Comparison of the Vegetation of the Indus Delta with that of the Sundribuns.

We reproduced on the first page of this article a statement made by J. D. Hooker in his 'Sketch of the Flora of British India': "The Indus Delta repeats the vegetation of the Sundribuns of Bengal, with a greatly reduced number of species." Let us see how far this is correct.

1. Number of species.

If we consider the indigenous species only (and we shall do this throughout) we arrive at the following data for the two regions.¹

Region	Families	Genera	Species	Ratio
Indus Delta	61	184	279	1 : 3 : 4.5
Sundribuns	72	230	304	1 : 3.1 : 4.2

The difference in the number of species in the two areas is only 25 in favour of the Sundribuns. When counting up the species of this area we considered all the entries made by Prain which were not marked with an asterisk. Prain distinguishes by this sign the plants which are planted or cultivated.

There are at least about a dozen plants in Prain's list which he did not mark with an asterisk, but which might be put under the introduced plants. But this is, in most cases, a difficult question to settle and scarcely two botanists would agree in individual instances. In addition, we must not forget that the Sundribuns are much better explored than the Indus Delta. Prain says in the Introduction that the investigation of the flora of the Sundribuns has occupied the attention of the officers in charge of the Royal Botanic Gardens

¹ All the information regarding the Sundribuns is based on D. Prain, *Flora of the Sundribuns*. In *Rec Bot. Surv. Ind.* II (1903) no. 4.

since 1796. Men like Griffith, Falconer, Thomson, Clarke, Gamble, Heinig, Gammie and Prain examined that area and what the latter offers us in his monograph is the combined result of over a hundred years' effort. Whilst systematic exploration was going on in the Sundribuns all the time, the vegetation of the Indus Delta was practically neglected, except for the meagre and very one-sided information we from time to time receive from the Forest, Agriculture and Revenue Departments. We have reason to believe that the flora of the Indus Delta as soon as better known will prove numerically richer in species and genera than that of the Sundribuns. We are not so sure that the same will be the case with regards to the number of families. According to our present knowledge the ratio of families, genera and species is about the same in both areas, *viz.* 1 : 3 : 4, roughly taken.

The following table shows the relation between the Dicotyledons and Monocotyledons in the two areas. The Monocotyledons are better represented in the Sundribuns than they are in the Indus Delta :

Region	Dicotyledons		Monocotyledons		Ratio of	
	Genera	Species	Genera	Species	Genera	Species
Indus Delta ...	139	211	44	67	3'1 : 1	3'1 : 1
Sundribuns ...	168	220	62	84	2'7 : 1	2'6 : 1

2. Composition of the floras of the Indus Delta and the Sundribuns.

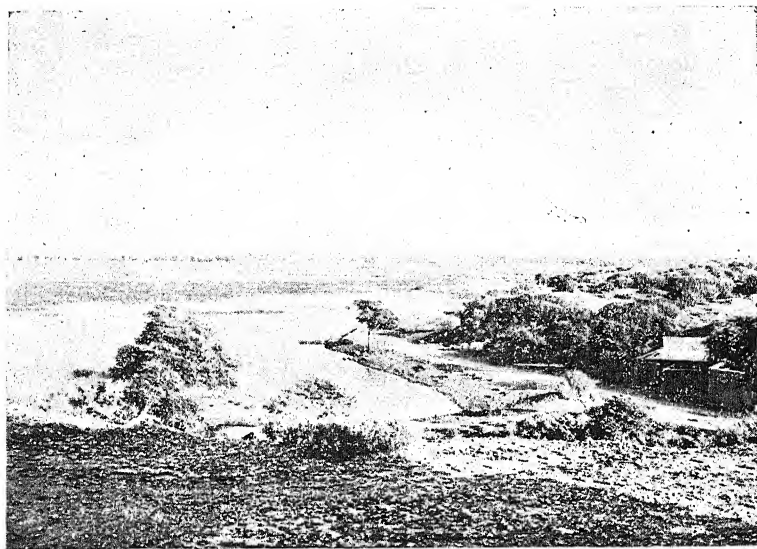
A peculiar interest attaches to these two deltas : Both are situated in the N. corner of a sea, of the Arabian Sea and the Bay of Bengal respectively, both are near the Tropic of Cancer, the Indus Delta a little to the N. of it, and the Sundribuns slightly to the S., both are formed by large rivers taking their origin in close proximity in the Himalayas, both show more or less the same topographical features, the flowers of both are subject to similar ecological and physiological influences, both are open to the immigration of species from vast areas,—but here the difference comes in. It is the plant-geographical position of the two deltas that has produced the two vastly different floras. A glance at the map will at once show the great possibilities of immigration and transport by river and sea, and these possibilities are more numerous in the East than they are in the West. If, in spite of these advantages of the Sundribuns, its flora is comparatively poor, we can find an explanation only in the fact that the soil- and water-conditions

of the delta have not been favourable to most immigrants that must have tried, in the course of thousands and perhaps millions of years, to force an entrance into the savannahs and swamps of the Sundribuns. It would be a fascinating study to find out what seeds of plants have been carried down by the rivers and washed ashore by the sea without ever awakening to new life. It would certainly make a valuable contribution to plant-geography and ecology.

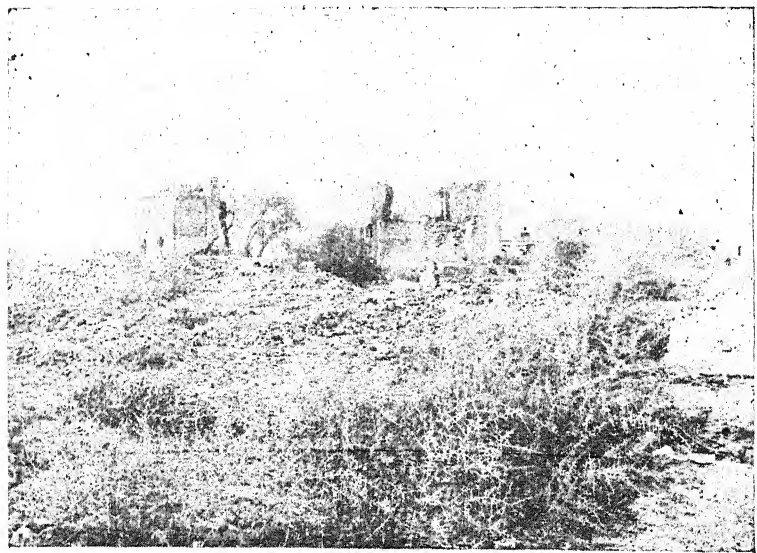
In order to get a more accurate insight into the relations of the two floras, and especially for the convenience of all those who feel inclined to tackle the innumerable botanical and biological problems that slumber in the waters and marshes of the two deltas, we subjoin a list of the indigenous plants that up to now have been discovered in the Indus Delta and the Sundribuns.

We add a column to the list which shows whether a species is a herb (H), an undershrub (U), a shrub (S) or a tree (T).

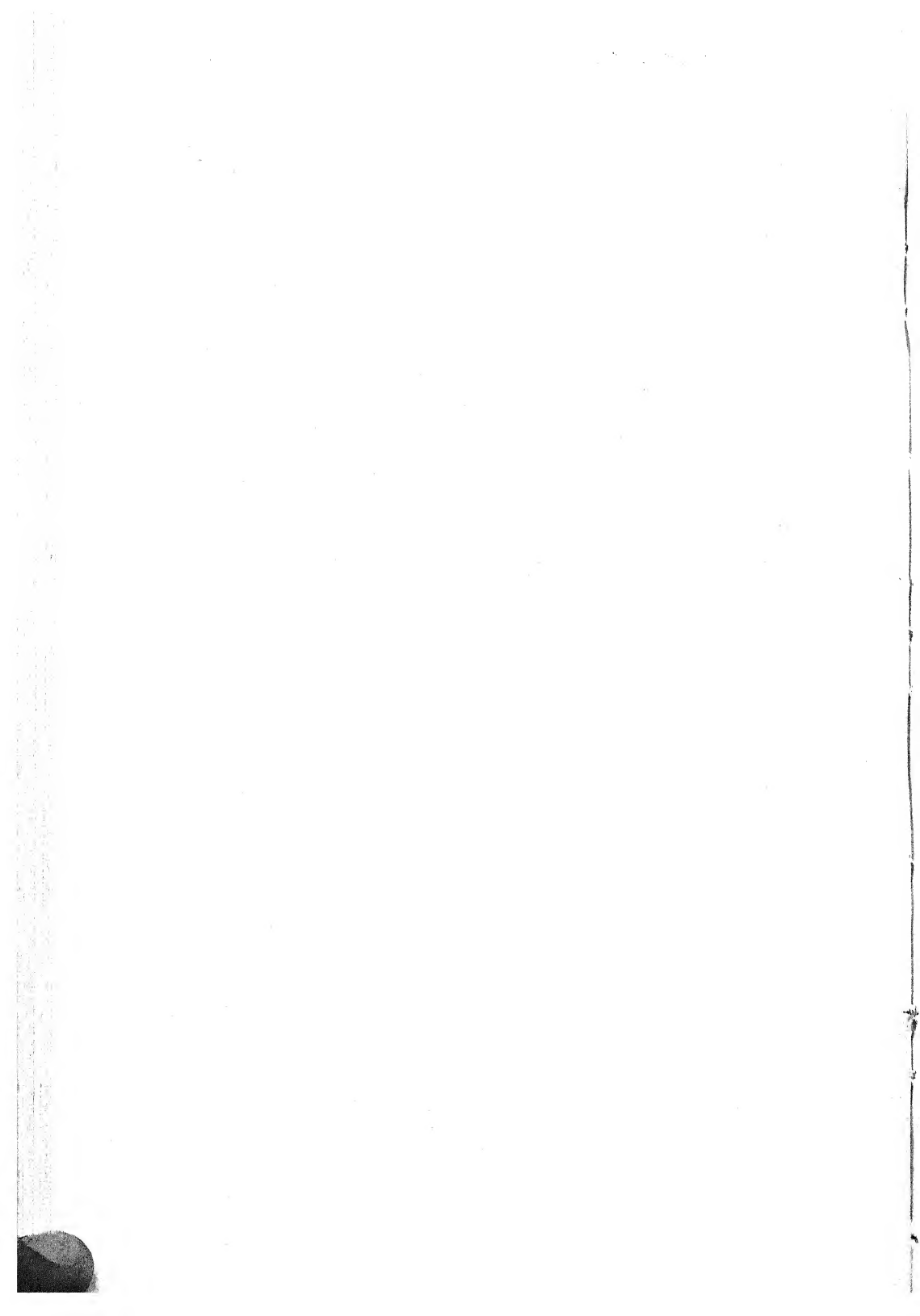
Family	Species	Habit	Indus Delta	Sundribuns
Ranunculaceae.	<i>Naravelia acylanica</i> DC. ...	S		*
Menispermaceae.	<i>Cocculus pendulus</i> Diels. ...	S	*	
	<i>Tinospora malabarica</i> Miers ...	S		*
Nymphaeaceae.	<i>Nymphaea rubra</i> Roxb. ...	H	*	
	" <i>stellata</i> Willd. ...	H	*	
	<i>Nelumbium speciosum</i> Willd. ...	H	*	
Cruciferae.	<i>Farsetia Jacquemontii</i> Hook. f. & Th. ...	H	*	
	<i>Senebiera pinnatifida</i> DC. ...	H		*
Capparidaceae.	<i>Cleome brachycarpa</i> Vahl ...	H	*	
	" <i>viscosa</i> Linn. ...	H	*	*
	<i>Gynandropsis pentaphylla</i> DC. ...	H	*	*
	<i>Maerua arenaria</i> Hook. f. & Th. ...	S	*	
	<i>Cadaba indica</i> Lam. ...	S	*	
	<i>Capparis decidua</i> Pax ...	S	*	
	" <i>sepiaria</i> Linn. ...	S		*
Resedaceae.	<i>Ochradenus baccatus</i> Del. ...	H	*	
Bixaceae.	<i>Flacourtia sepiaria</i> Roxb. ...	S		*
Polygalaceae.	<i>Polygala irregularis</i> Boiss. ...	H	*	
Caryophyllaceae.	<i>Polycarpaea spicata</i> Wight & Arn. ...	H	*	
Portulacaceae.	<i>Portulaca oleracea</i> Linn. ...	H	*	*
	" <i>quadrifida</i> Linn. ...	H	*	
Tamaricaceae.	<i>Tamarix Troupii</i> Holc ...	ST	*	
	" <i>dioica</i> Roxb. ...	T	*	
	" <i>articulata</i> Vahl ...	ST	*	
	" <i>indica</i> Roxb. ...	ST		*



No. 29. A view of the country between Isakhan's Tomb and Tatta. Near the lake: *Euphorbia*, *Tamarix*, *Acacia* and some cultivated trees. Beyond the lake various *Chenopods*.



No. 30. Tatta—Tombs. Shrubs and trees of *Capparis decidua*.

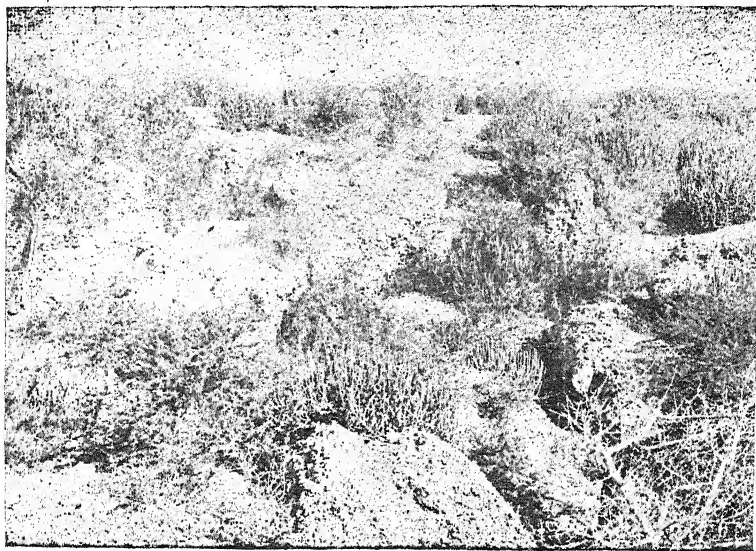


Family	Species	Habit	Indus	Delta	Sundri- buns
Elatinaceae.	<i>Bergia odorata</i> Edgew. ...	H	*		
	" <i>ammannioides</i> Roxb. ...	H	*		
Malvaceae.	<i>Sida spinosa</i> Linn. ...	H	*		
	" <i>grewioides</i> Guill. Perr. & A. Rich. ...	H	*		
	<i>Abutilon indicum</i> Sw. ...	U	*		*
	" <i>hirtum</i> G. Don. ...	U			*
	" <i>polyandrum</i> W. & A. ...	U	*		
	" <i>muticum</i> Sw. ...	U	*		
	" <i>fruticosum</i> Guill. Per. & A. Rich. ...	U	*		
	<i>Malachra capitata</i> Linn. ...	H			*
	<i>Senra incana</i> Cav. ...	U	*		
	<i>Hibiscus tortuosus</i> Wall. ...	T			*
	" <i>tiliaceus</i> Linn. ...	T			*
	<i>Thespesia populnea</i> Cor. ...	T	*		*
Tiliaceae.	<i>Gossypium Stocksii</i> Mast. ...	S	*		
	" <i>Bakeri</i> Watt. ...	S	*		
	<i>Grewia populifolia</i> Vahl ...	S	*		
	" <i>asiatica</i> Linn. ...	S	*		
	" <i>villosa</i> Willd. ...	S	*		
	<i>Triumfetta rotundifolia</i> Lam. ...	H	*		
	" <i>pentandra</i> A. Rich. ...	H	*		
	<i>Corchorus antichorus</i> Raeusch. ...	H	*		
	" <i>tridens</i> Linn. ...	H	*		
	" <i>acutangulus</i> Lam. ...	H	*		*
Sterculiaceae.	<i>Brownlonia lanceolata</i> Benth. ...	T			*
	<i>Melhania Denhamii</i> R. Br. ...	S	*		
	<i>Heritiera minor</i> Roxb. ...	T			*
Zygophyllaceae.	<i>Kleinhovia hospita</i> Linn. ...	T			*
	<i>Tribulus terrestris</i> Linn. ...	H	*		
	" <i>alatus</i> Del. ...	H	*		
	<i>Zygophyllum simplex</i> Linn. ...	H	*		
Geraniaceae.	<i>Fagonia cretica</i> Linn. ...	H	*		
	<i>Erodium cicutarium</i> L'Herit. ...	H	*		
	<i>Oxalis corniculata</i> Linn. ...	H			*
Rutaceae.	<i>Glycosmis pentaphylla</i> Corr. ...	S			*
	<i>Micromelum pubescens</i> Bl. ...	T			*
	<i>Paramignya longispina</i> Hook. f. ...	U			*
	<i>Aegle marmelos</i> Corr. ...	T			*
Burseraceae.	<i>Commiphora Mukul</i> Engl. ...	S	*		
Meliaceae.	<i>Amoora cucullata</i> Roxb. ...	T			*
	<i>Carapa moluccensis</i> Lam. ...	T			*
	" <i>obovata</i> Bl. ...	T			*

Family	Species	Habit	Indus Delta	Sundri- buns
Oleaceae.	<i>Olea scandens</i> Roxb. ...	S		*
Celastraceae.	<i>Gymnosporia montana</i> Benth. ...	T	*	
	<i>Salacia prinoides</i> DC. ...	ST		*
Rhamnaceae.	<i>Zizyphus oenoplia</i> Mill. ...	S		*
	" <i>rotundifolia</i> Lam. ...	S	*	
Ampelidaceae.	<i>Vitis quadrangularis</i> Wall. ...	S		*
	" <i>latifolia</i> Roxb. ...	S		*
	" <i>trifolia</i> Linn. ...	S		*
	<i>Leca sambucina</i> Willd. ...	S		*
Sapindaceae.	<i>Cardiospermum Halicacabum</i> Linn. ...	H		*
	<i>Allophylus Cobbe</i> Bl. ...	S		*
Anacardiaceae.	<i>Aphania Danura</i> Radlk. ...	S		*
	<i>Bouea burmanica</i> Griff. ...	T		*
	<i>Odina Wodier</i> Roxb. ...	T		*
Legumin.—Papil.	<i>Crotalaria verrucosa</i> Linn. ...	U		*
	" <i>retusa</i> Linn. ...	U		*
	" <i>Saliana</i> Andr. ...	U		*
	" <i>Burhia</i> Hamilt. ...	U	*	
	" <i>juncea</i> Linn. ...	H	*	
	" <i>modicaginea</i> Lam. ...	H	*	
	<i>Indigofera cordifolia</i> Heyne. ...	H	*	
	" <i>uniflora</i> Buch. ...	H	*	
	" <i>anabaptista</i> Steud. ...	H	*	
	" <i>paucifolia</i> Del. ...	S	*	
	" <i>viscosa</i> Lam. ...	H	*	
	<i>Tephrosia tenuis</i> Wall. ...	H	*	
	" <i>petrosa</i> Blatt. & Hall. ...	H	*	
	<i>Sesbania aculeata</i> Poir. ...	H	*	
	<i>Taverniera cuneifolia</i> Arn. ...	U	*	
	<i>Alhagi camelorum</i> Fisch. ...	S	*	
	<i>Aeschynomene indica</i> Linn. ...	U	*	
	" <i>aspera</i> Linn. ...	S	*	
	<i>Alysicarpus vaginalis</i> DC. ...	U	*	
	<i>Desmodium umbellatum</i> DC. ...	ST		*
	<i>Abrus precatorius</i> Linn. ...	S		*
	<i>Teramnus flexilis</i> Benth. ...	S		*
	<i>Mucuna gigantea</i> DC. ...	S		*
	<i>Erythrina indica</i> Lam. ...	T		*
	<i>Canavalia lineata</i> DC. ...	H		*
	" <i>turgida</i> Grah. ...	H		*
	<i>Phaseolus adenanthus</i> Mey. ...	H		*
	" <i>trilobus</i> Ait. ...	H		*
	<i>Vigna luteola</i> Benth. ...	H		*

Family	Species	Habit	Indus Delta	Sundri-buns
Legumin.—Papil.	<i>Atylosia scarabaeoides</i> Benth. ...	H		*
	<i>Flemingia congesta</i> Roxb. ...	S		*
	<i>Dalbergia spinosa</i> Roxb. ...	S		*
	" <i>torta</i> Grah. ...	S		*
	<i>Rhynchosia minima</i> DC. ...	H	*	
	<i>Pongamia glabra</i> Vent. ...	T	*	*
	<i>Derris sinuata</i> Thw. ...	S		*
	" <i>scandens</i> Benth. ...	S		*
	" <i>uliginosa</i> Benth. ...	S		*
	<i>Caesalpinia Bonducella</i> Flem. ...	S		*
Legum.—Cacsalp.	" <i>Nuga</i> Ait. ...	S		*
	<i>Mezoneuron cucullatum</i> W. & A. ...	S		*
	<i>Cassia Sophera</i> Linn. ...	U		*
	" <i>Tora</i> Linn. ...	H		*
	<i>Cynometra mimosoides</i> Wall. ...	T		*
	<i>Intsia bijuga</i> O. Kuntze. ...	T		*
	<i>Entada scandens</i> , Benth. ...	S		*
Legum.—Mim.	<i>Prosopis spicigera</i> Linn. ...	H	*	*
	<i>Mimosa hamata</i> Willd. ...	S	*	
	<i>Acacia arabica</i> Willd. ...	T	*	
	" <i>Farnesiana</i> Willd. ...	T	*	
	" <i>Senegal</i> Willd. ...	T	*	
	" <i>tomentosa</i> Willd. ...	T		*
	" <i>concinna</i> DC. ...	T		*
	" <i>Intsia</i> Willd. ...	T		*
Droseraceae.	<i>Aldrovanda vesiculosa</i> Linn. ...	H		*
Rhizophoraceae.	<i>Rhizophora mucronata</i> Lam. ...	T	*	*
	" <i>conjugata</i> Linn. ...	T	*	*
	<i>Cericeps Roxburghiana</i> Arn. ...	T	*	*
	" <i>Candolleana</i> Arn. ...	T	*	
	<i>Kandelia Rheedei</i> W. & A. ...	T		*
	<i>Bruguiera gymnorrhiza</i> Lam. ...	T	*	*
	" <i>parviflora</i> W. & A. ...	T		*
Combretaceae.	<i>Lumnitzera racemosa</i> Willd. ...	T		*
Myrtaceae.	<i>Eugenia fruticosa</i> Roxb. ...	ST		*
	<i>Barringtonia racemosa</i> Bl. ...	T		*
	" <i>acutangula</i> Gaertn. ...	T		*
Lythraceae.	<i>Ammannia baccifera</i> Linn. ...	H	*	
	" <i>sp.</i> ...	H		*
	<i>Sonneratia apetala</i> Ham. ...	T		*
	" <i>acida</i> Linn. f. ...	T	*	*
Turneraceae.	<i>Turnera ulmifolia</i> Linn. ...	U		*
Passifloraceae.	<i>Passiflora suberosa</i> Linn. ...	H		*
Cucurbitaceae.	<i>Momordica Charantia</i> Linn. ...	H	*	

Family	Species	Habit	Indus Delta	Sundri- buns.
Cucurbitaceae.	<i>Momordica dioica</i> Roxb. ...	H		*
	<i>Trichosanthes cucumerina</i> Linn.	H		*
	" <i>palmata</i> Roxb. ...	H		*
	<i>Luffa graveolens</i> Roxb. ...	H		*
	<i>Cucumis trigonus</i> Roxb. ...	H		*
	" <i>prophetae</i> Linn. ...	H	*	
	<i>Citrullus Colocynthis</i> Schrad. ...	H	*	
	<i>Coccinia indica</i> W. & A. ...	H	*	
	<i>Melothria maderaspatana</i> Cogn. ...	H	*	
	<i>Kedrostis rostrata</i> Cogn. ...	H	*	
	<i>Corallocarpus epigaeus</i> C.B. Clarke ...	H	*	
	<i>Cephalandra indica</i> Naud. ...	H		*
	<i>Zehneria umbellata</i> Thw. ...	H		*
	<i>Sesuvium Portulacastrum</i> Linn.	H		*
Ficoidaceae.	<i>Trianthema monogyna</i> Linn. ...	H	*	*
	" <i>pentandra</i> Linn. ...	H	*	
	<i>Orygia decumbens</i> Forsk. ...	H	*	
Rubiaceae.	<i>Mollugo hirta</i> Thunb. ...	H	*	
	<i>Oldenlandia diffusa</i> Roxb. ...	H		*
	<i>Petunga Roxburghii</i> DC. ...	ST		*
	<i>Vangueria spinosa</i> Roxb. ...	S		*
	<i>Ixora parviflora</i> Vahl. ...	T		*
Compositae.	" <i>coccinea</i> Linn. ...	S		*
	<i>Morinda bracteata</i> Roxb. ...	T		*
	<i>Vernonia cinerea</i> Less. ...	H	*	*
	" <i>cinerascens</i> Schultz ...	H	*	
	<i>Ageratum conyzoides</i> Linn. ...	H		*
	<i>Grangea maderaspatana</i> Poir. ...	H	*	*
	<i>Conyza semi-pinnatifida</i> Wall. ...	H		*
	<i>Blumea amplexans</i> DC. ...	H		*
	<i>Pluchea tomentosa</i> DC. ...	H	*	
	" <i>lanceolata</i> C. B. Clarke. ...	H	*	
	" <i>indica</i> Less. ...	H		*
	<i>Sphaeranthus africanus</i> Linn. ...	H		*
	<i>Gnaphalium pulvinatum</i> Del. ...	H	*	
	<i>Inula grantioides</i> Boiss. ...	H	*	
	<i>Vicoa cernua</i> Daltz. & Gibs. ...	H	*	
	<i>Pulicaria angustifolia</i> DC. ...	H	*	
	" <i>Stocksii</i> Hook. f. ...	H	*	
	<i>Eclipta erecta</i> Linn. ...	H	*	
	<i>Xanthium spinosum</i> Linn. ...	H		*
	<i>Blainvillea rhomboidea</i> Cass. ...	H	*	
	<i>Wedelia scandens</i> C. B. Clarke. ...	H		*



No. 31. Limestone-conglomerate near Tatta: *Commiphora Mukul*,
Euphorbia caducifolia, *Acacia arabica*.



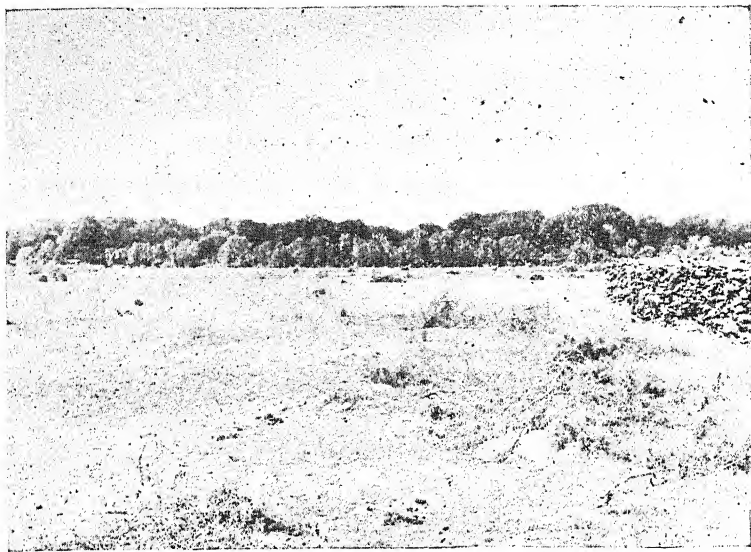
No. 32. Gravelly and sandy plain between the tombs near Tatta.
Commiphora Mukul, *Zizyphus*, *Capparis*, *Calotropis*.

Family	Species	Habit	Indus Delta	Sundri- buns
Compositae.	<i>Wedelia calendulacea</i> Less. ...	H		*
	<i>Echinops echinatus</i> DC. ...	H	*	
	<i>Volutarella divaricata</i> Benth. ...			
	& Hook. f. ...	H	*	
	<i>Dicoma tomentosa</i> Cass. ...	H	*	
	<i>Cnicus arvensis</i> Hoffm. ...	H		*
	<i>Sonchus oleraceus</i> Linn. ...	H	*	
	<i>Launaea chondrilloides</i> Hook. f. ...	H	*	
	" <i>nudicaulis</i> Hook. f. ...	H	*	
	" <i>pinnatifida</i> Cass. ...	H		*
Goodeniaceae.	<i>Scaevola frutescens</i> K. Krause ...	S	*	
	" <i>Plumieri</i> Vahl ...	S	*	
Plumbaginaceae.	<i>Statice Stocksii</i> Boiss. ...	H	*	
	<i>Aegialitis rotundifolia</i> Roxb. ...	ST		*
Myrsinaceae.	<i>Aegiceras majus</i> Gaertn. ...	T	*	*
Ebenaceae.	<i>Diospyros montana</i> Roxb. ...	T		*
	" <i>Embryopteris</i> Pers. ...	T		*
Salvadoraceae.	<i>Salvadora persica</i> Linn. ...	T	*	
	" <i>oleoides</i> Dene. ...	T	*	
	<i>Azima tetracantha</i> Lam. ...	S		*
Apocynaceae.	<i>Cerbera Odollam</i> Gaertn. ...	T		*
	<i>Parsonsia spiralis</i> Wall. ...	S		*
	<i>Nerium odorum</i> Soland. ...	S	*	
Asclepiadaceae.	<i>Hemidesmus indicus</i> R. Br. ...	S		*
	<i>Finlaysonia obovata</i> Wall. ...	S		*
	<i>Periploca aphylla</i> Dene. ...	S	*	
	" sp. ...	S	*	
	<i>Oxystelma esculentum</i> R. Br. ...	U	*	*
	<i>Calotropis procera</i> R. Br. ...	S	*	
	" <i>gigantea</i> R. Br. ...	S		*
	<i>Pentatropis cynanchoides</i> R. Br. ...	U	*	
	" <i>microphylla</i> W. & A. ...	H		*
	<i>Daemia extensa</i> R. Br. ...	U	*	*
	<i>Sarcostemma Stocksii</i> Hook. f. ...	S	*	
	<i>Sarcolobus globosus</i> Wall. ...	S		*
	" <i>carinatus</i> Wall. ...	S		*
	<i>Dregea volubilis</i> Benth. ...	S		*
	<i>Leptadenia Spartium</i> Wight ...	S	*	
	<i>Tylophora tenuis</i> Bl. ...	H		*
	<i>Dischidia nummularia</i> R. Br. ...	H		*
	<i>Hoya parasitica</i> Wall. ...	S		*
Gentianaceae.	<i>Enicostemma littorale</i> Bl. ...	E	*	
	<i>Hoppea dichotoma</i> Willd. ...	H		*
	<i>Limnanthemum cristatum</i> Griseb. ...	H		*

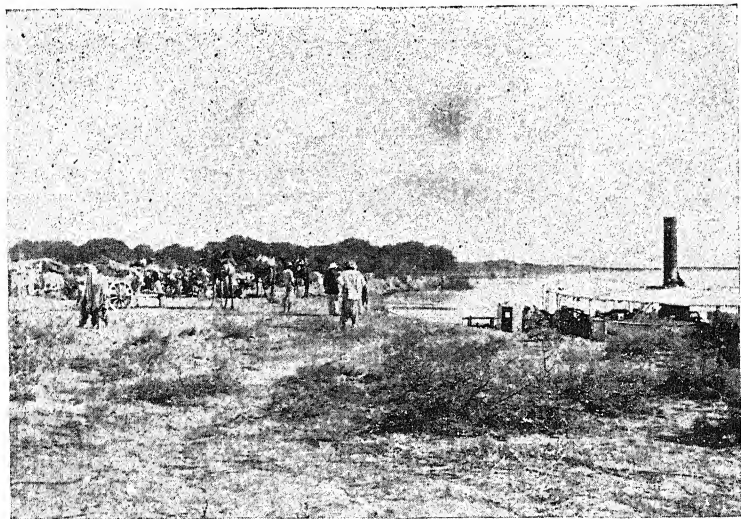
Family	Species	Habit	Indus	Delta	Sundri-buns
Hydrophyllaceae. Boraginaceae.	<i>Hydrolea zeylanica</i> Vahl ...	H			*
	<i>Cordia Myxa</i> Linn.	T	*		*
	" <i>Rothii</i> Roem. & Schult....	T	*		
	<i>Goldenia procumbens</i> Linn. ...	H			*
	<i>Heliotropium indicum</i> Linn. ...	H			*
	" <i>ophioglossum</i> Stocks	H	*		
	" <i>calcareum</i> Stocks...	H	*		
	" <i>ovalifolium</i> Forsk.	H	*		
	" <i>undulatum</i> Vahl ...	H	*		
	" <i>paniculatum</i> R. Br.	H	*		
Convolvulaceae.	" <i>rariflorum</i> Stocks...	H	*		
	<i>Trichodesma indicum</i> R. Br. ...	H	*		
	<i>Stictocardia tiliacfolia</i> Hallier f.	S			*
	<i>Cressa cretica</i> Linn.	H	*		
	<i>Convolvulus scandicus</i> Stocks ...	U	*		
	" <i>Rottlerianus</i> Choisy..	U	*		
	" <i>microphyllus</i> Sieb. ...	U	*		
	" <i>rhyniospermus</i> Hochst.	U	*		
	" <i>arvensis</i> Linn.	H	*		
	" <i>sp.</i>	H	*		
	<i>Merremia chryseides</i> Hallier f....	H	*		
	" <i>aegyptia</i> Linn.	H	*		
	" <i>hederacea</i> Hallier f....	S			*
	<i>Ipomoea longiflora</i> R. Br. ...	S			*
	" <i>paniculata</i> R. Br. ...	S			*
	" <i>biloba</i> Forsk.	H	*		*
	" <i>aquatica</i> Forsk.	H	*		*
	" <i>illustris</i> Prain ...	S			*
Solanaceae.	" <i>sepiaria</i> Koen.	H			*
	" <i>eriocarpa</i> R. Br.	H	*		
	<i>Rivea hypocrateriformis</i> Choisy	S	*		
	<i>Ouscuta reflexa</i> Roxb.	H			*
	<i>Solanum nigrum</i> Linn.	HU	*		*
	" <i>xanthocarpum</i> Schrad. & Wendl.	H	*		*
	<i>Solanum albicaule</i> Kotschy ...	H	*		
	" <i>argenteum</i> Dun.	S			*
	" <i>trilobatum</i> Linn.	U			*
	<i>Physalis minima</i> Linn.	H	*		
Scrophulariaceae.	<i>Withania somnifera</i> Dun.	H	*		
	<i>Lycium barbarum</i> Linn.	S	*		
	<i>Datura fastuosa</i> Linn.	H	*		
	<i>Angelonia grandiflora</i> C. Morr.	H			*
	<i>Linaria ramosissima</i> Wall. ...	H	*		

Family	Species	Habit	Indus Delta	Sundri- buns
Scrophulariaceae.	<i>Schweinfurthia sphaerocarpa</i>	H	*	
	<i>A. Braun</i>	H	*	
	<i>Limnophila gratioloides</i> R. Br...	H		*
	" <i>gratissima</i> Bl.	H		*
	<i>Herpestis Monnieria</i> H.B. & K...	H		*
	<i>Vandellia crustacea</i> Benth. ...	H		
	<i>Bonnaya veronicaefolia</i> Spreng	H	*	
	<i>Peplidium humifusum</i> Del. ...	H	*	
	<i>Lindenbergia abyssinica</i> Hochst.	H	*	
	" <i>urticaefolia</i> Link....	H		*
Orobanchaceae.	<i>Scoparia dulcis</i> Linn. ...	H	*	
Lentibulariaceae.	<i>Cistanche tubulosa</i> Wight	H		
	<i>Utricularia stellaris</i> Linn. f. ...	H		*
Bignoniaceae.	" <i>flexuosa</i> Vahl	H	*	*
	<i>Tecomella undulata</i> Seem. ...	T		*
Acanthaceae.	<i>Dolichandrone Rhoedei</i> Seem. ...	T		
	<i>Blepharis indica</i> T. Anders. ...	S	*	
	<i>Ruellia patula</i> Jacq. ...	S	*	
	" <i>prostrata</i> Poir. ...	H	*	
	<i>Barleria Prionitis</i> Linn. ...	S	*	
	" <i>acanthoides</i> Vahl	U	*	
	" <i>Hochstetteri</i> Nees	S	*	
	<i>Justicia heterocarpa</i> T. Anders. ...	H		*
	<i>Hygrophila quadrivalvis</i> Nees ...	H		*
	" <i>phlomidis</i> Nees	H		*
	" <i>spinosa</i> T. Anders.	H		*
	<i>Hemigraphis hirta</i> T. Anders. ...	H		*
	<i>Acanthus ilicifolius</i> Linn. ...	U		*
	" <i>volubilis</i> Wall.	U		*
	<i>Lantana indica</i> Roxb. ...	S		*
	" <i>trifolia</i> Linn. ...	S		*
	<i>Lippia geminata</i> H. B. & K. ...	S		*
Verbenaceae.	" <i>nodiflora</i> Rich. ...	H	*	*
	<i>Premna integrifolia</i> Linn. ...	ST		*
	<i>Vitex trifolia</i> Linn. f. ...	ST		*
	" <i>Negundo</i> Linn. ...	ST		*
	<i>Olerodendron Phlomidis</i> Linn. f.	S	*	
	" <i>inermis</i> Gaertn. ...	U		*
	" <i>neriifolium</i> Wall....	U		*
	" <i>Siphonanthus</i> R. Br.	S		*
	<i>Avicennia officinalis</i> Linn. ...	T	*	*
	" <i>alba</i> Bl.	S		*
Labiales.	<i>Ocimum sanctum</i> Linn. ...	HU	*	
	" <i>canum</i> Sims	HU	*	

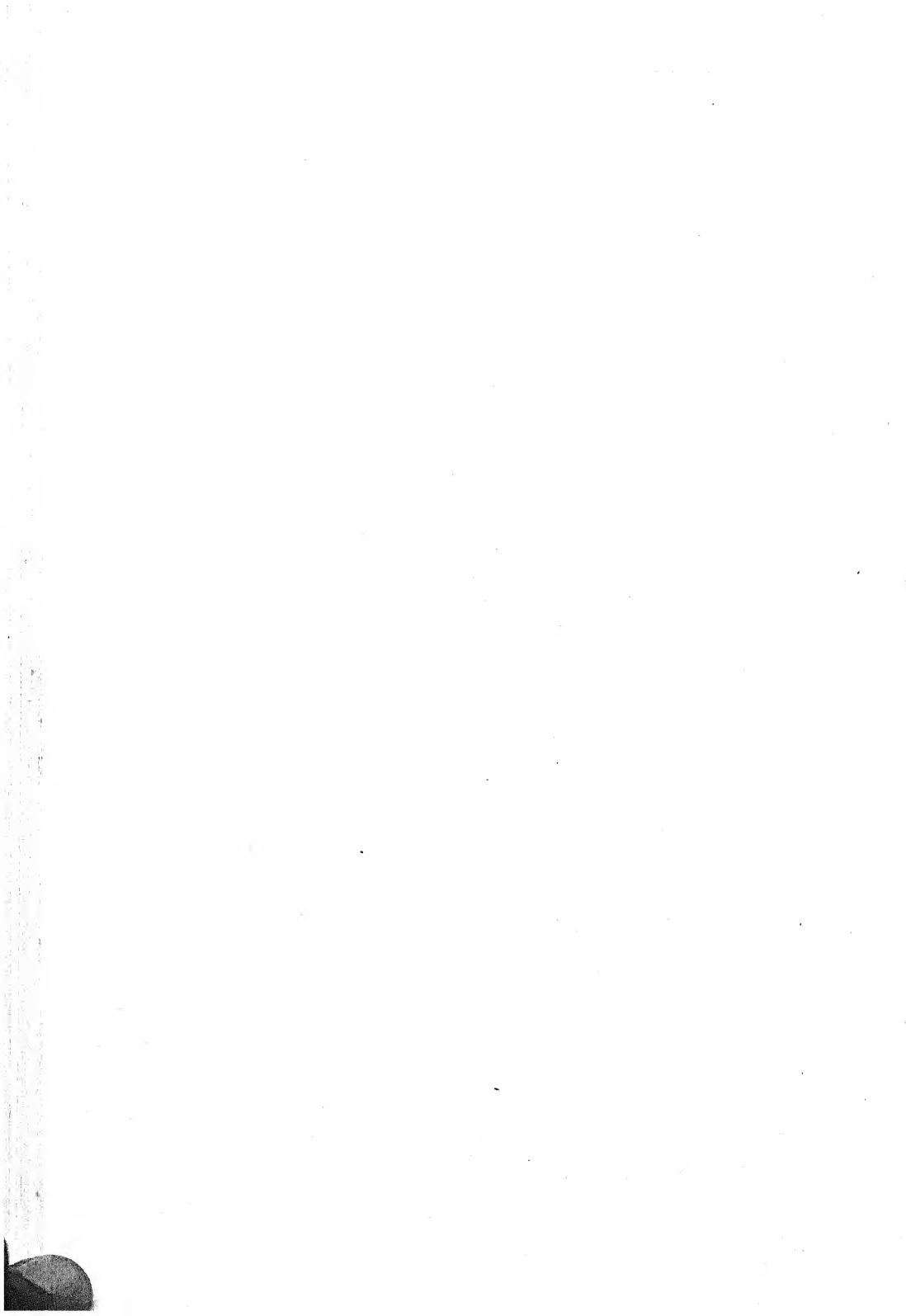
Family	Species	Habit	Indus	Delta	Sundri- buns
Labiateae.	<i>Ocimum basilicum</i> Linn. ...	H			*
	<i>Anisomeles ovata</i> R. Br. ...	H			*
	<i>Leucas urticaefolia</i> R. Br. ...	H	*		
	„ <i>linifolia</i> Spreng. ...	H			*
Nyctaginaceae.	<i>Salvia aegyptiaca</i> Linn. ...	H	*		
	<i>Boerhaavia diffusa</i> Linn. ...	H	*		
Amarantaceae.	„ <i>verticillata</i> Poir. ...	H	*		
	<i>Celosia argentea</i> Linn. ...	H	*		
	<i>Digera arvensis</i> Forsk. ...	H	*		
	<i>Amarantus viridis</i> Linn. ...	H	*		*
	„ <i>polygamus</i> Linn. ...	H	*		
	<i>Aerua tomentosa</i> Forsk. ...	H	*		
	„ <i>pseudo-tomentosa</i> Blatt. & Hall. ...	H	*		
	<i>Achyranthes aspera</i> Linn. ...	H	*		
	<i>Nothosaerua brachiata</i> Wight ...	H	*		
	<i>Pupalia lappacea</i> Moq. ...	H	*		
	<i>Psilotrichum ferrugineum</i> Moq. ...	H			*
	<i>Alternanthera triandra</i> Lam. ...	H	*		*
	„ <i>nodiflora</i> Br. ...	H	*		
Chenopodiaceae.	<i>Chenopodium murale</i> Linn. ...	H	*		
	<i>Atriplex Stocksii</i> Boiss. ...	H	*		
	<i>Arthrocnemum indicum</i> Moq. ...	U	*		*
	<i>Salicornia brachiata</i> Roxb. ...	U			*
	<i>Suaeda fruticosa</i> Forsk. ...	S	*		
	„ <i>nudiiflora</i> Moq. ...	U	*		
	„ <i>monoica</i> Forsk. ...	U	*		
	„ <i>Maritima</i> Dumort. ...	H			*
	<i>Haloxylon recurvum</i> Bunge. ...	S	*		
	<i>Salsola foetida</i> Del. ...	S	*		
Polygonaceae.	<i>Basella rubra</i> Linn. ...	H			*
	<i>Polygonum plebejum</i> R.Br. ...	H	*		
Aristolochiaceae.	<i>Aristolochia bracteata</i> Retz. ...	H	*		
Lauraceae.	„ <i>indica</i> Linn. ...	U			*
	<i>Cassytha filiformis</i> Linn. ...	H			*
Loranthaceae.	<i>Loranthus Scurrula</i> Linn. ...	S			*
	„ <i>longiflorus</i> Desr. ...	S			*
	„ <i>globosus</i> Roxb. ...	S			*
Euphorbiaceae,	<i>Viscum monoicum</i> Roxb. ...	S			*
	<i>Euphorbia caducifolia</i> Ham. ...	S	*		
	„ <i>hypericifolia</i> Linn. ...	H	*		*
	„ <i>hirta</i> Linn. ...	H	*		
	„ <i>pilulifera</i> Linn. ...	H	*		*
	„ <i>granulata</i> Forsk. ...	H	*		



No. 33. Bughar on the banks of the Indus. In the foreground: *Tamarix dioica*. In the background: *Tamarix Troupii* and behind it a forest of *Acacia arabica*.



No. 34. Bughar on the right bank of the Indus. Background: a forest of *Acacia arabica*, *Phyllanthus reticulata*. In foreground: scrub of *Tamarix dioica*.



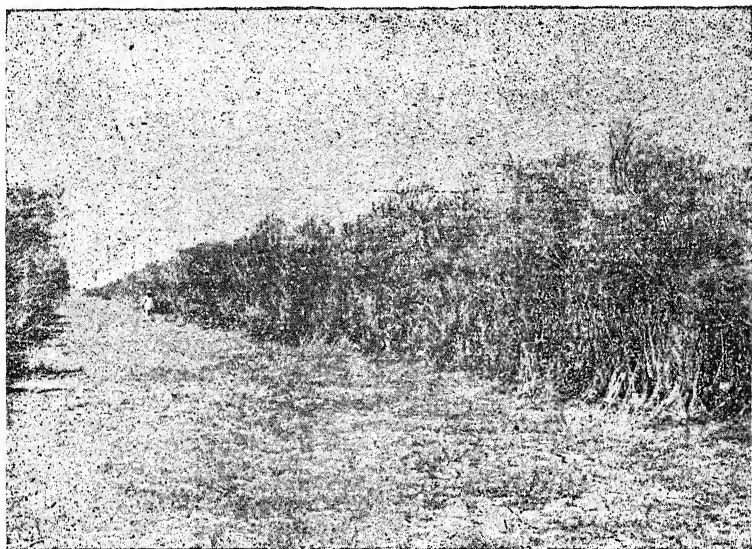
Family	Species	Habit	Indus Delta	Sundri- buns
Euphorbiaceae.	<i>Euphorbia Clarkeana</i> Hook. f. ...	H	*	
	" <i>jodhpurensis</i> Blatt. & Hall. ...	H	*	
	" <i>thymifolia</i> Burm. ...	H		*
	<i>Andrachne aspera</i> Spreng. ...	H	*	
	" <i>sp. nov.</i> ...	H	*	
	<i>Bridelia stipularis</i> Bl. ...	S		*
	<i>Agaveia bacciformis</i> A. Juss. ...	HU		*
	<i>Phyllanthus reticulatus</i> Poir. ...	S	*	
	" <i>Niruri</i> Linn. ...	H	*	*
	<i>Breynea rhamnoides</i> Muell.-Arg. ...	ST		*
	<i>Cyclostemon assamicus</i> Hook. f. ...	T		*
	<i>Antidesma Ghaesembilla</i> Gaertn. ...	T		*
	<i>Croton oblongifolius</i> Roxb. ...	T		*
	<i>Chrozophora plicata</i> A. Juss. ...	HU		*
	<i>Acalypha indica</i> Linn. ...	H		*
	<i>Trewia nudiflora</i> Linn. ...	T		*
	<i>Mallotus repandus</i> Muell.-Arg. ...	S		*
	<i>Sapium indicum</i> Willd. ...	T		*
	<i>Excoecaria Agallocha</i> Linn. ...	T		*
Urticaceae.	<i>Trema orientalis</i> Bl. ...	T		*
	<i>Streblus asper</i> Lour. ...	ST		*
	<i>Ficus retusa</i> Linn. ...	T		*
	" <i>infectoria</i> Roxb. ...	T		*
	" <i>Rumphii</i> Bl. ...	T		*
	" <i>religiosa</i> Linn. ...	T		*
	" <i>glomerata</i> Roxb. ...	T	*	
Casuarinaceae.	<i>Casuarina equisetifolia</i> Forst. ...	T		*
Salicaceae.	<i>Populus euphratica</i> Oliv. ...	T	*	
Ceratophyllaceae.	<i>Ceratophyllum demersum</i> Linn. ...	H		*
Gnetaceae.	<i>Ephedra foliata</i> Boiss. ...	S	*	
Hydrocharitaceae.	<i>Hydrilla verticillata</i> Casp. ...	H		*
	<i>Vallisneria spiralis</i> Linn. ...	H	*	*
	<i>Lagarosiphon Roxburghii</i> Benth. ...	H		*
Orchidaceae.	<i>Ottelia alismoides</i> Pers. ...	H		*
	<i>Oberonia Gammiei</i> King & Pantling ...	H		*
	<i>Dendrobium anceps</i> Sw. ...	H		*
	" <i>Pierardi</i> Roxb. ...	H		*
	<i>Cirrhopetalum Roxburghii</i> Lindl. ...	H		*
	<i>Trias oblonga</i> Lindl. ...	H		*
	<i>Luisia teretifolia</i> Gaud. ...	H		*
	" <i>brachystachys</i> Bl. ...	H		*
	<i>Saccolabium ochraceum</i> Lindl. ...	H		*

Family	Species	Habit	Indus Delta	Sundri- bans
Orchidaceae.	<i>Saccolabium longifolium</i> Hook. f.	H		*
	" <i>papillosum</i> Lindl. ...	H		*
	<i>Sarcanthus appendiculatus</i> Hook. f. ...	H		*
	<i>Sarcanthus insectifer</i> Reichb. ...	H		*
	<i>Cleisostoma ramosum</i> Hook. f. ...	H		*
Scitamineae.	<i>Alpinia Allughas</i> Roscoe ...	H		*
	<i>Zingiber Casumunar</i> Roxb. ...	H		*
Amaryllidaceae.	<i>Crinum asiaticum</i> Linn. ...	H	*	*
Disoscoriaceae.	<i>Dioscorca pentaphylla</i> Linn. ...	H		*
Liliaceae.	<i>Asphodelus tenuifolius</i> Cav. ...	H		*
	<i>Asparagus gharoensis</i> Blatter ...	S		
	" <i>dumosus</i> Baker ...	S	*	
Commelinaceae.	" <i>deltiae</i> Blatter ...	S	*	
	<i>Commelina benghalensis</i> Linn. ...	H		*
	" <i>albescens</i> Hassk. ...	H	*	
	<i>Ancilema nudiflorum</i> R. Br. ...	H		*
Flagellariaceae.	<i>Flagellaria indica</i> Linn. ...	S		*
Palmae.	<i>Nipa fruticans</i> Wurm. ...	T		*
	<i>Phoenix paludosa</i> Roxb. ...	T		*
	<i>Calamus tenuis</i> Roxb. ...	S		*
	<i>Dacmonorops Jenkinsianus</i> Mart. ...	S		*
	<i>Cocos nucifera</i> Linn. ...	T	*	*
Pandanaeeae.	<i>Pandanus tectorius</i> Soland. ...	S	*	*
	" <i>foetidus</i> Roxb. ...	S		*
Typhaceae.	<i>Typha angustata</i> Bory & Chaub. ...	H	*	*
	" <i>elephantina</i> Roxb. ...	H	*	*
Araceae.	<i>Cryptocoryne ciliata</i> Fisch. ...	H		*
	<i>Pistia stratiotes</i> Linn. ...	H		*
Lemnaceae.	<i>Lemna</i> sp. ...	H	*	
Alismaceae.	<i>Sagittaria sagittifolia</i> Linn. ...	H	*	
Naiadaceae.	<i>Ruppia rostellata</i> Koch ...	H		*
	<i>Zanichellia palustris</i> Linn. ...	H	*	
	<i>Najas minor</i> All. ...	H		*
	" sp. ...	H	*	
	" sp. ...	H	*	
Cyperaceae.	<i>Aponogeton monostachyum</i> Linn. ...	H	*	
	<i>Kyllingia triceps</i> Rottb. ...	H		*
	<i>Pycneus polystachus</i> Beauv. ...	H		*
	<i>Cyperus inundatus</i> Roxb. ...	H		*
	" <i>malaccensis</i> Lam. ...	H		*
	" <i>tegetiformis</i> Roxb. ...	H		*
	" <i>scariosus</i> R. Br. ...	H		*
	" <i>exaltatus</i> Retz. ...	H		*

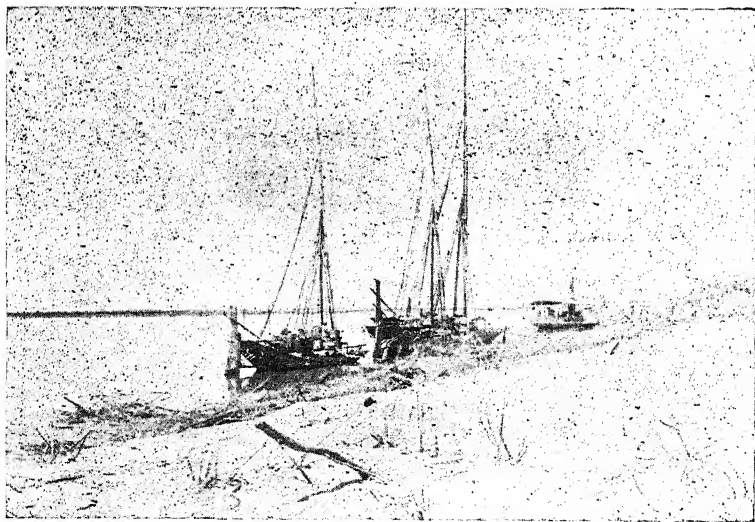
Family	Species	Habit	Indus	Delta	Sundri- buns
Cyperaceae.	<i>Cyperus stoloniferus</i> Retz. ...	H	*		
	" <i>alopecuroides</i> Rottb. ...	H	*		
	" <i>Haspan</i> Linn. ...	H	*		
	" <i>arenarius</i> Retz. ...	H	*		
	" <i>tegetum</i> Roxb. ...	H	*		
	" <i>rotundus</i> Linn. ...	H	*		
	<i>Mariscus albescens</i> Gaud. ...	H			*
	<i>Eleocharis spiralis</i> R. Br. ...	H			*
	" <i>atropurpureus</i> Kunth. ...	H	*		
	<i>Fimbristylis ferruginca</i> Vahl ...	H	*		*
	<i>Fimbristylis polytrichoides</i> Vahl ...	H			*
	" <i>sub-bispicata</i> Nees ...				
	" & <i>Meyen</i> ...	H			*
	" <i>monostachya</i> Hassk. ...	H			*
	" <i>dichotoma</i> Vahl ...	H	*		
	<i>Scirpus quinquefarius</i> Ham. ...	H	*		
	" <i>maritimus</i> Linn. ...	H			
	" <i>grossus</i> Linn. f. ...	H			*
	" <i>littoralis</i> Schrad. ...	H			*
	" <i>triqueter</i> Linn. ...	H			*
	" <i>articulatus</i> Linn. ...	H			*
	<i>Cladium riparium</i> Benth. ...	H			*
	<i>Scirpodendron costatum</i> Kurz....	H			*
	<i>Imperata arundinacea</i> Cyrill. ...	H			*
Gramineae.	<i>Coix Lachryma-Jobi</i> Linn. ...	H	*		
	<i>Hemarthria compressa</i> R. Br. ...	H	*		
	<i>Saccharum spontaneum</i> Linn. ...	H	*		*
	" <i>Griffithii</i> Munro ...	H	*		
	" <i>Ravennae</i> Linn. ...	H	*		
	<i>Vetiveria zizanioides</i> Stapf ...	H			*
	<i>Amphilophis glabra</i> Stapf ...	H			*
	<i>Chrysopogon aciculatus</i> Trin. ...	H			*
	<i>Dichanthium annulatum</i> Stapf... ..	H	*		
	<i>Cymbopogon Jwarancusa</i> Schult. ...	H	*		
	<i>Digitaria sanguinalis</i> Scop. ...	H	*		
	" <i>pennata</i> Chiov. ...	H	*		
	<i>Eriochloa ramosa</i> Kuntze ...	H	*		*
	<i>Paspalum scrobiculatum</i> Linn....	H	*		*
	" <i>vaginatum</i> Sw. ...	H			*
	<i>Urochloa reptans</i> Stapf ...	H			*
	" <i>setigera</i> Stapf ...	H	*		
	<i>Paspalidium geminatum</i> Stapf... ..	H	*		
	<i>Echinochloa colona</i> Link. ...	H	*		*
	" <i>Crus-Galli</i> P. Beauv ...	H	*		*

Family	Species	Habit	Indus Delta	Sundri- buns
Gramineae.	<i>Echinochloa stagnina</i> P. Beauv...	H	*	
	<i>Setaria lutescens</i> Hubb. ...	H		
	" <i>verticillata</i> Beauv. ...	H	*	*
	<i>Chamaecraphis spinescens</i> Poir. ...	H		*
	<i>Panicum antidotale</i> Retz. ...	H	*	
	" <i>proliferum</i> Lam. ...	H		*
	" <i>repens</i> Linn. ...	H		*
	" <i>Myurus</i> H. B. & K. ...	H		*
	<i>Pennisetum cenchroides</i> Rich. ...	H	*	
	<i>Cenchrus biflorus</i> Roxb. ...	H	*	
	" <i>catharticus</i> Del. ...	H	*	
	<i>Phragmites karka</i> Trin. ...	H	*	*
	<i>Sporobolus arabicus</i> Boiss. ...	H	*	
	" <i>tremulus</i> Kunth ...	H		*
	<i>Heleochoa dura</i> Boiss. ...	H	*	
	<i>Aristida Adscensionis</i> Linn. ...	H	*	
	" <i>funiculata</i> Trin. ...	H	*	
	<i>Tragus racemosus</i> Scop. ...	H	*	
	<i>Desmostachya cynosuroides</i> Stapf	H	*	
	<i>Eragrostis ciliaris</i> Link. ...	H	*	
	" <i>interrupta</i> Beauv. ...	H	*	
	" <i>amabilis</i> Wight & Arn. ...	H	*	
	" <i>tenella</i> L. & S. ...	H		*
	<i>Diplachne fusca</i> Beauv. ...	H	*	*
	<i>Chloris villosa</i> Pers. ...	H	*	
	" <i>barbata</i> Sw. ...	H	*	*
	<i>Cynodon dactylon</i> Pers. ...	H	*	
	<i>Eleusine flagellifera</i> Nees ...	H	*	
	" <i>aristata</i> Ehrenb. ...	H	*	
	" <i>aegyptiaca</i> Desf. ...	H	*	*
	" <i>indica</i> Gaertn. ...	H		*
	<i>Oryza coarctata</i> Roxb. ...	H	*	*
	<i>Leersia hexandra</i> Sw. ...	H		*
	<i>Zoysia pungens</i> Willd. ...	H		*
	<i>Aeluropus villosus</i> Trin. ...	H	*	
	<i>Myriostachya Wightiana</i> Hook. f.	H		*

An analysis of the above catalogue will reveal some interesting facts.



No. 35. A forest of *Tamarix Troupii* Hole, near Sujawal on the Indus, with a broad clearing through it, parallel to the river,



No. 36. At Sujawal on the Indus, Blown sand covering up *Tamarix* scrub.

We give first a list of the 72 families of the Sundribuns plants arranged according to number of species belonging to each:

Species Genera				Species Genera			
Leguminosae	...	32	21	Apocynaceae	...	2	2
Gramineae	...	27	22	Gentianaceae	...	2	2
Cyperaceae	...	19	9	Lentibulariaceae	...	2	1
Euphorbiaceae	...	16	14	Scitamineae	...	2	2
Orchidaceae	...	13	8	Commelinaceae	...	2	2
Compositae	...	12	11	Pandanaceae	...	2	1
Asclepiadaceae	...	12	11	Typhaceae	...	2	1
Verbenaceae	...	12	6	Araceae	...	2	2
Convolvulaceae	...	9	4	Naiadaceae	...	2	2
Cucurbitaceae	...	7	6	Ranunculaceae	...	1	1
Malvaceae	...	6	4	Menispermaceae	...	1	1
Rhizophoraceae	...	6	4	Cruciferae	...	1	1
Rubiaceae	...	6	5	Bixaceae	...	1	1
Acanthaceae	...	6	3	Portulacaceae	...	1	1
Urticaceae	...	6	3	Tamaricaceae	...	1	1
Scrophulariaceae	...	5	5	Geraniaceae	...	1	1
Palmae	...	5	5	Olacaceae	...	1	1
Rutaceae	...	4	4	Celastraceae	...	1	1
Ampelidaceae	...	4	2	Rhamnaceae	...	1	1
Solanaceae	...	4	1	Droseraceae	...	1	1
Labiatae	...	4	3	Combretaceae	...	1	1
Chenopodiaceae	...	4	4	Turneraceae	...	1	1
Loranthaceae	...	4	2	Passifloraceae	...	1	1
Hydrocharitaceae	...	4	4	Plumbaginaceae	...	1	1
Capparidaceae	...	3	3	Myrsinaceae	...	1	1
Meliaceae	...	3	2	Salvadoraceae	...	1	1
Sapindaceae	...	3	3	Hydrophyllaceae	...	1	1
Myrtaceae	...	3	2	Bignoniaceae	...	1	1
Lythraceae	...	3	2	Aristolochiaceae	...	1	1
Boraginaceae	...	3	3	Lauraceae	...	1	1
Amarantaceae	...	3	3	Casuarinaceae	...	1	1
Tiliaceae	...	2	2	Ceratophyllaceae	...	1	1
Sterculiaceae	...	2	2	Amaryllidaceae	...	1	1
Anacardiaceae	...	2	2	Dioscoreaceae	...	1	1
Ficoidaceae	...	2	2	Liliaceae	...	1	1
Ebenaceae	...	2	1	Flagellariaceae	...	1	1

Of the 87 families found in both deltas taken together, the following families are represented

Only in the Indus Delta

Nymphaeaceae
Resedaceae
Polygalaceae
Caryophyllaceae

Only in the Sundribuns

Ranunculaceae
Bixaceae
Rutaceae
Meliaceae

Hydrophyllaceae
Lentibulariaceae
Lauraceae
Loranthaceae

Only in the Indus Delta

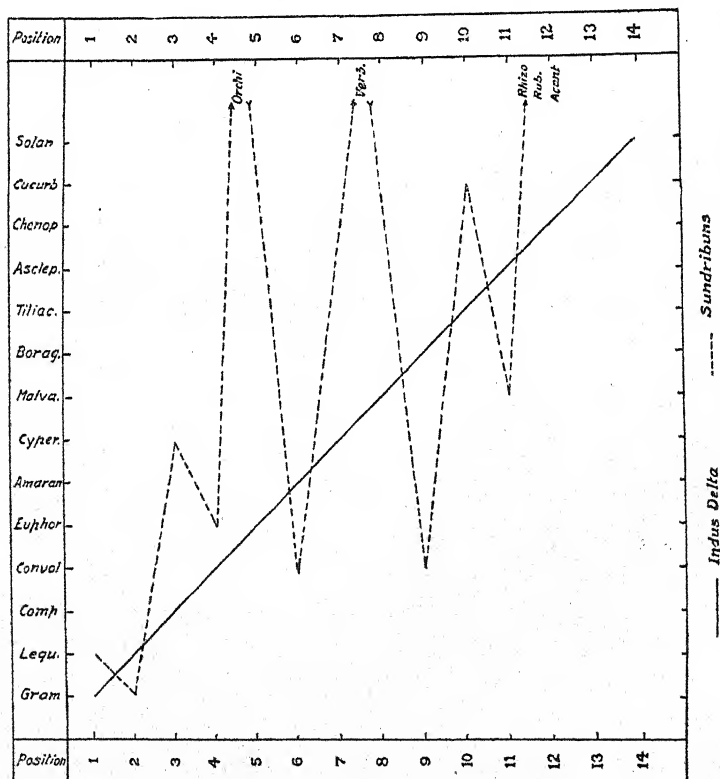
Elatinaceae
 Zygophyllaceae
 Burseraceae
 Goodeniaceae
 Orobanchaceae
 Nyctaginaceae
 Polygonaceae
 Salicaceae
 Gnetaceae
 Lemnaceae
 Alismaceae

Only in the Sundribuns

Olacaceae
 Ampelidaceae
 Sapindaceae
 Anacardiaceae
 Droseraceae
 Combretaceae
 Myrtaceae
 Turneraceae
 Passifloraceae
 Rubiaceae
 Ebenaceae
 Casuarinaceae
 Ceratophyllaceae
 Orchidaceae
 Scitamineae
 Dioscoreaceae
 Flagellariaceae
 Araceae

Dominant families.

The following graph shows the 14 dominant orders of the two deltas. It is interesting to note that the Orchids, an order not represented at all in the Indus Delta, take the 5th place in the Sundribuns.



Graph 15.—The dominant families in the Indus Delta and the Sundribuns

Regarding the genera, we observe in both deltas 336 genera. Of these 67 ($\frac{1}{3}$) are common to both areas, 113 (out of 184) have been found in the Indus Delta only, and 156 (out of 230) in the Sundribuns only.

Genera common to both areas.

<i>Oleome</i>	<i>Calotropis</i>	<i>Commelina</i>
<i>Gynandropsis</i>	<i>Pentatropis</i>	<i>Cocos</i>
<i>Capparis</i>	<i>Daemia</i>	<i>Pandanus</i>
<i>Portulaca</i>	<i>Cordia</i>	<i>Typha</i>
<i>Tamarix</i>	<i>Merremia</i>	<i>Naias</i>
<i>Abutilon</i>	<i>Ipomoea</i>	<i>Cyperus</i>
<i>Thespesia</i>	<i>Solanum</i>	<i>Eleocharis</i>
<i>Corchorus</i>	<i>Limnophila</i>	<i>Fimbristylis</i>
<i>Crotalaria</i>	<i>Lippia</i>	<i>Scirpus</i>
<i>Pongamia</i>	<i>Olerodendron</i>	<i>Saccharum</i>
<i>Acacia</i>	<i>Avicennia</i>	<i>Eriochloa</i>
<i>Rhizophora</i>	<i>Ocimum</i>	<i>Paspalum</i>
<i>Ceriops</i>	<i>Amarantus</i>	<i>Urochloa</i>
<i>Bruguiera</i>	<i>Alternanthera</i>	<i>Echinochloa</i>
<i>Ammannia</i>	<i>Arthrocnemum</i>	<i>Setaria</i>
<i>Sonneratia</i>	<i>Suaeda</i>	<i>Panicum</i>
<i>Momordica</i>	<i>Aristolochia</i>	<i>Phragmites</i>
<i>Trianthema</i>	<i>Euphorbia</i>	<i>Sporobolus</i>
<i>Vernonia</i>	<i>Phyllanthus</i>	<i>Diplachne</i>
<i>Pluchea</i>	<i>Ficus</i>	<i>Chloris</i>
<i>Launaea</i>	<i>Vallisneria</i>	<i>Bleusine</i>
<i>Aegiceras</i>	<i>Crinum</i>	<i>Oryza</i>
<i>Oxystelma</i>		

The following 113 genera are represented only in the Indus Delta:—

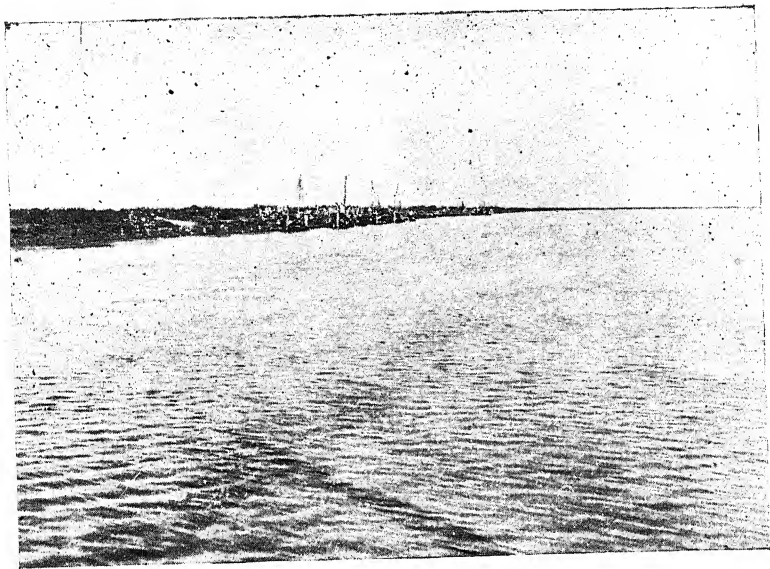
<i>Cocculus</i>	<i>Gymnosporia</i>	<i>Inula</i>	<i>Physalis</i>
<i>Nymphaea</i>	<i>Crotalaria</i>	<i>Vicoa</i>	<i>Withania</i>
<i>Nelumbium</i>	<i>Indigofera</i>	<i>Pulicaria</i>	<i>Lycium</i>
<i>Farsetia</i>	<i>Tephrosia</i>	<i>Eclipta</i>	<i>Datura</i>
<i>Maerua</i>	<i>Sesbania</i>	<i>Blainvillea</i>	<i>Linaria</i>
<i>Cadaba</i>	<i>Taverniera</i>	<i>Echinops</i>	<i>Schweinfurthia</i>
<i>Ochradenus</i>	<i>Alhagi</i>	<i>Volutarella</i>	<i>Bonnaya</i>
<i>Polygala</i>	<i>Aeschynomene</i>	<i>Dicoma</i>	<i>Peplidium</i>
<i>Polycarpaea</i>	<i>Alysicarpus</i>	<i>Sonchus</i>	<i>Lindenbergia</i>
<i>Bergia</i>	<i>Rhynchosia</i>	<i>Scaevola</i>	<i>Cistanche</i>
<i>Sida</i>	<i>Prosopis</i>	<i>Statice</i>	<i>Tecomella</i>
<i>Senra</i>	<i>Mimosa</i>	<i>Salvadora</i>	<i>Blepharis</i>
<i>Gossypium</i>	<i>Trichosanthes</i>	<i>Nerium</i>	<i>Ruellia</i>
<i>Grewia</i>	<i>Citrullus</i>	<i>Periploca</i>	<i>Barleria</i>
<i>Triumfetta</i>	<i>Coccinia</i>	<i>Sarcostemma</i>	<i>Justicia</i>
<i>Melhania</i>	<i>Melothria</i>	<i>Leptadenia</i>	<i>Salvia</i>
<i>Tribulus</i>	<i>Kedrostis</i>	<i>Enicostemma</i>	<i>Boerhaavia</i>
<i>Zygophyllum</i>	<i>Corallocarpus</i>	<i>Trichodesma</i>	<i>Celosia</i>
<i>Fagonia</i>	<i>Orygia</i>	<i>Cressa</i>	<i>Digera</i>
<i>Erodium</i>	<i>Mollugo</i>	<i>Convolvulus</i>	<i>Aerva</i>
<i>Commiphora</i>	<i>Gnaphalium</i>	<i>Rivea</i>	<i>Achyranthes</i>

<i>Nothosacra</i>	<i>Populus</i>	<i>Hemarthria</i>	<i>Aristida</i>
<i>Pupalia</i>	<i>Ephedra</i>	<i>Cymbopogon</i>	<i>Tragus</i>
<i>Chenopodium</i>	<i>Asparagus</i>	<i>Dichanthium</i>	<i>Desmostachya</i>
<i>Atriplex</i>	<i>Lenna</i>	<i>Digitalia</i>	<i>Cynodon</i>
<i>Haloxylon</i>	<i>Sagittaria</i>	<i>Paspalidium</i>	<i>Aeluropus</i>
<i>Salsola</i>	<i>Aponogeton</i>	<i>Pennisetum</i>	
<i>Polygonum</i>	<i>Zanichellia</i>	<i>Cenchrus</i>	
<i>Andrachne</i>	<i>Coix</i>	<i>Eleocharis</i>	

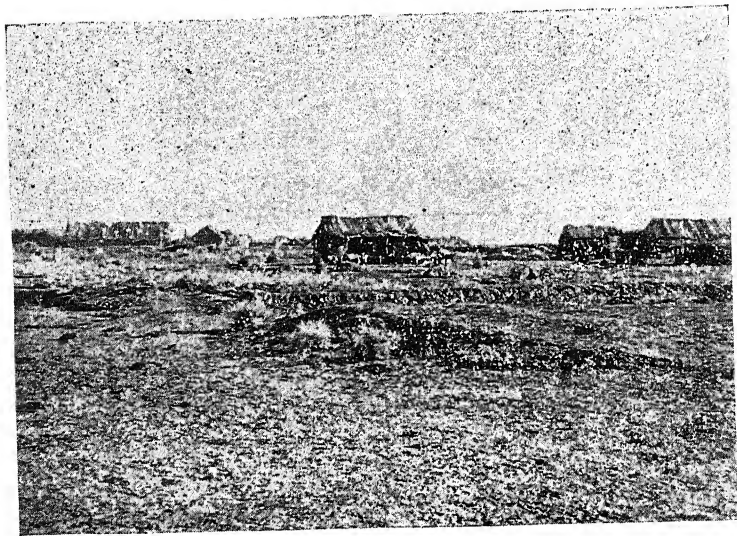
Nearly all these genera are characteristic of the tropical and N. African-Indian Desert.

The following 156 genera are represented in the Sundribuns only :—

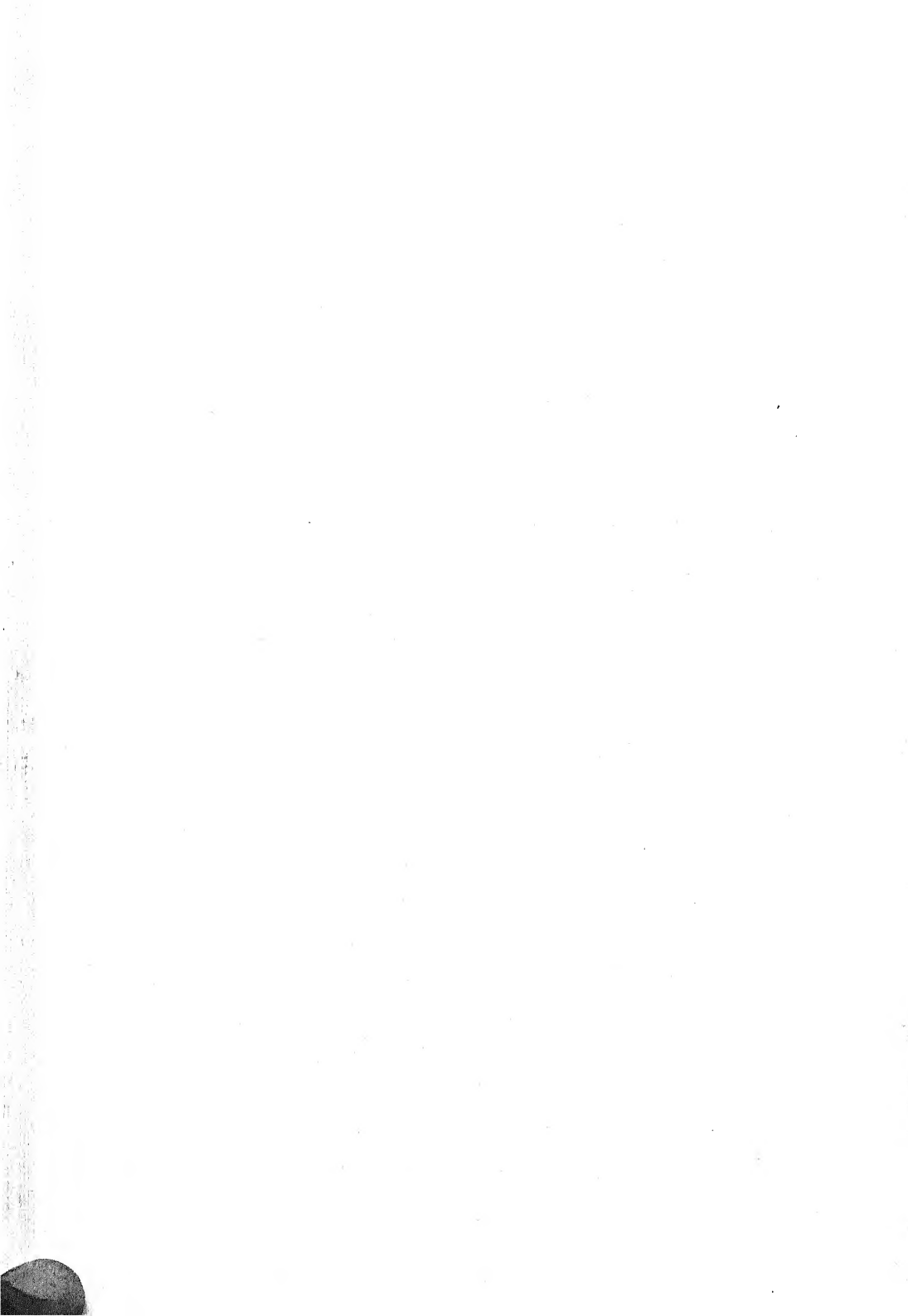
<i>Naravelia</i>	<i>Cassia</i>	<i>Hopaea</i>	<i>Casuarina</i>
<i>Tinospora</i>	<i>Cynometra</i>	<i>Limnanthemum</i>	<i>Ceratophyllum</i>
<i>Senebiera</i>	<i>Intsia</i>	<i>Hydrolea</i>	<i>Hydrilla</i>
<i>Flacourtia</i>	<i>Entada</i>	<i>Coldenia</i>	<i>Lagarosiphon</i>
<i>Malachra</i>	<i>Aldrovanda</i>	<i>Sistocardia</i>	<i>Ottelia</i>
<i>Hibiscus</i>	<i>Kandelia</i>	<i>Cuscuta</i>	<i>Oberonia</i>
<i>Brownlowia</i>	<i>Lumnitzera</i>	<i>Angelonia</i>	<i>Dendrobium</i>
<i>Heritiera</i>	<i>Eugenia</i>	<i>Herpestis</i>	<i>Cirrhopetalum</i>
<i>Kleinhovia</i>	<i>Barringtonia</i>	<i>Vandellia</i>	<i>Trias</i>
<i>Oxalis</i>	<i>Turnera</i>	<i>Scoparia</i>	<i>Luisia</i>
<i>Glycosmis</i>	<i>Passiflora</i>	<i>Utricularia</i>	<i>Saccolabium</i>
<i>Microlemum</i>	<i>Trichosanthes</i>	<i>Dolichandrone</i>	<i>Sarcanthus</i>
<i>Paramignya</i>	<i>Luffa</i>	<i>Hygrophila</i>	<i>Cleisostoma</i>
<i>Aegle</i>	<i>Cephalandra</i>	<i>Hemigraphis</i>	<i>Alpinia</i>
<i>Amoora</i>	<i>Zehneria</i>	<i>Acanthus</i>	<i>Zingiber</i>
<i>Carapa</i>	<i>Sesuvium</i>	<i>Lantana</i>	<i>Dioscorea</i>
<i>Olaa</i>	<i>Oldenlandia</i>	<i>Premna</i>	<i>Asphodelus</i>
<i>Salacia</i>	<i>Petunga</i>	<i>Vitex</i>	<i>Aneilema</i>
<i>Vitis</i>	<i>Vangueria</i>	<i>Anisomeles</i>	<i>Flagellaria</i>
<i>Leca</i>	<i>Icra</i>	<i>Psilotrichum</i>	<i>Nipa</i>
<i>Cardiospermum</i>	<i>Morinda</i>	<i>Salicornia</i>	<i>Phoenix</i>
<i>Allophylus</i>	<i>Agratum</i>	<i>Basella</i>	<i>Calamus</i>
<i>Aphania</i>	<i>Conyza</i>	<i>Cassytha</i>	<i>Daemonorops</i>
<i>Bouea</i>	<i>Blumea</i>	<i>Loranthus</i>	<i>Cryptocoryne</i>
<i>Odina</i>	<i>Sphaeranthus</i>	<i>Viscum</i>	<i>Pistia</i>
<i>Desmodium</i>	<i>Xanthium</i>	<i>Bridelia</i>	<i>Ruppia</i>
<i>Abrus</i>	<i>Wedelia</i>	<i>Agyneia</i>	<i>Kyllingia</i>
<i>Teramnus</i>	<i>Onicus</i>	<i>Breyneia</i>	<i>Pycneus</i>
<i>Mucuna</i>	<i>Aegialitis</i>	<i>Cyclostemon</i>	<i>Mariscus</i>
<i>Erythrina</i>	<i>Diospyros</i>	<i>Antidesma</i>	<i>Cladium</i>
<i>Canavalia</i>	<i>Azima</i>	<i>Croton</i>	<i>Scirpodendron</i>
<i>Phaseolus</i>	<i>Cerbera</i>	<i>Chrozophora</i>	<i>Imperata</i>
<i>Vigna</i>	<i>Parsonsia</i>	<i>Acalypha</i>	<i>Vetiveria</i>
<i>Alylosia</i>	<i>Hemidesmus</i>	<i>Trewia</i>	<i>Amphilophis</i>
<i>Flemingia</i>	<i>Finlaysonia</i>	<i>Mallotus</i>	<i>Chrysopogon</i>
<i>Dalbergia</i>	<i>Sarcocobus</i>	<i>Sapium</i>	<i>Chamaeraphis</i>
<i>Derris</i>	<i>Tylophora</i>	<i>Excoecaria</i>	<i>Leersia</i>
<i>Cacalpinia</i>	<i>Dischidia</i>	<i>Trema</i>	<i>Zoysia</i>
<i>Mezoneuron</i>	<i>Hoya</i>	<i>Strebus</i>	<i>Myriostachya</i>



No. 37. On the Hajamro River. Dense forest of *Populus euphratica* and *Acacia Farnesiana* in the background.



No. 33. Doreen, a little village on the Hajamro River, built on sandy alluvium. Scanty growth of *Tamarix dioica*.



The dominant genera in both areas, considering the number of species in each, are:—

In the Indus Delta.	No. of species.	In the Sundribuns.
<i>Euphorbia</i> ...	7	
<i>Heliotropium</i> , <i>Convolvulus</i> ,	6	<i>Ipomoea</i> .
<i>Cyperus</i>		
<i>Abutilon</i> , <i>Indigofera</i> ...	5	
	4	<i>Solanum</i> , <i>Ficus</i> , <i>Fimbristylis</i> , <i>Scirpus</i> .
<i>Tamarix</i> , <i>Grewia</i> , <i>Corchorus</i> ,	3	<i>Vitis</i> , <i>Crotalaria</i> , <i>Derris</i> , <i>Acacia</i> , <i>Hygrophila</i> , <i>Clerodendron</i> , <i>Loranthus</i> , <i>Euphorbia</i> , <i>Saccolabium</i> .
<i>Crotalaria</i> , <i>Acacia</i> , <i>Ipomoea</i> ,		
<i>Solanum</i> , <i>Barleria</i> , <i>Suaeda</i> ,		
<i>Asparagus</i> , <i>Saccharum</i> ,		
<i>Echinochloa</i> , <i>Eragrostis</i> ,		
<i>Eleusine</i> .		

The other genera are represented by 2 or 1 species.

That the Indus Delta does not repeat the vegetation of the Sundribuns is evident from the following list which gives only 48 species as common to both areas.

Family.	Species.	Remarks regarding distribution.
Capparidac. ...	<i>Oleome viscosa</i> .	Throughout the trop. regions of the world.
	<i>Gynandropsis pentaphylla</i> .	Throughout the trop. regions of the world.
Portulacac. ...	<i>Portulaca oleracea</i> .	All warm countries.
Malvac. ...	<i>Abutilon indicum</i> .	Throughout the tropics.
	<i>Thespesia populnea</i> .	Maritime in trop. Africa and Asia.
Tiliac. ...	<i>Corchorus acutangulus</i> .	Tropics of nearly the whole world.
Leguminos - Papil.	<i>Pongamia glabra</i> .	Throughout trop. Asia.
Rhizophorac. ...	<i>Rhizophora mucronata</i> .	Maritime in tropics of Old World.
	" <i>conjugata</i> .	Maritime in tropics of Old World.
	<i>Cerlops Roxburghiana</i> .	Tidal from Sundribuns to Malacca.
Lythrac. ...	<i>Sonneratia acida</i> .	Tidal in India, Ceylon, etc.
Ficoideac. ...	<i>Trianthema monogyna</i> .	Most tropical countries.
Composit. ...	<i>Vernonia cinerea</i> .	Tropics of Old World.
	<i>Grangea maderaspatana</i>	Trop. and subtrop. Africa and Asia.

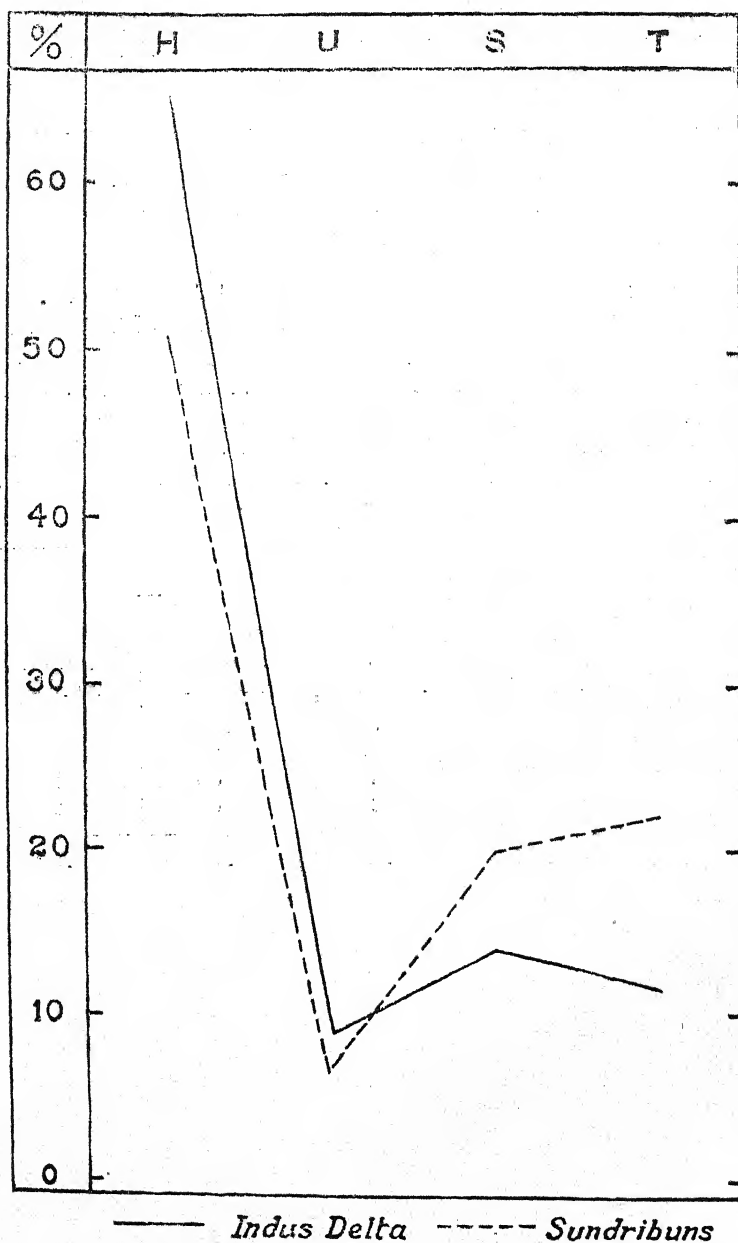
Family	Species	Remarks Regarding Distribution
Myrsinac. ...	<i>Aegiceras majus.</i>	Nearly all tropical coasts.
Asclepiadac. ...	<i>Oxystelma esculentum.</i>	Indo-Malayan.
	<i>Daemia extensa.</i>	Afghanistan, India, Ceylon.
Boraginac. ...	<i>Cordia Myxa.</i>	Egypt, trop. Asia and Australia.
Convolvulac. ...	<i>Ipomoea biloba.</i>	Sea-shores throughout tropics.
	„ <i>aquatica.</i>	Trop. Africa, Asia, Australia.
Solanac. ...	<i>Solanum nigrum.</i>	Cosmopolitan.
	„ <i>xanthocarpum.</i>	Indo-Malaya, Australia.
Verbenac. ...	<i>Lippia nodiflora.</i>	Most tropical and sub trop. regions.
	<i>Avicennia officinalis.</i>	Shores of Indian and Pacific oceans.
Labiata. ...	<i>Ocimum sanctum.</i>	From Arabia through India to Australia.
Amarantac. ...	<i>Amarantus viridis.</i>	All trop. countries.
	<i>Alternanthera triandra.</i>	All warm countries.
Chenopodiace. ...	<i>Arthrocnemum indicum.</i>	Trop. Africa, India, Ceylon.
Euphorbiac. ...	<i>Euphorbia hypericifolia.</i>	Almost throughout the tropics.
	„ <i>pilulifera.</i>	Most trop. and sub trop. countries.
	<i>Phyllanthus Niruri.</i>	Tropics generally, not in Australia.
Hydrocharitac.	<i>Vallisneria spiralis.</i>	Warm regions generally
Amoryllidac. ...	<i>Crinum asiaticum.</i>	Throughout trop. India, wild or cultivated.
Palmae ...	<i>Cocos nucifera.</i>	All tropical shores.
Pandanac. ...	<i>Pandanus tectorius.</i>	Sea-coast of India and Burma.
Typhac. ...	<i>Typha angustata.</i>	N. Africa, Asia, throughout India.
	„ <i>elephantina.</i>	N. Africa, N. W. India to Assam and southwards.
Cyperac. ...	<i>Fimbristylis ferruginea.</i>	Indo-Malaya to Australia.
Gramin. ...	<i>Saccharum spontaneum.</i>	Tropics of Old World.
	<i>Eriochloa ramosa.</i>	Most hot countries.
	<i>Paspalum scrobiculatum.</i>	Tropics of Old World.
	<i>Echinochloa colona.</i>	Most warm countries.
	„ <i>Crus-Galli.</i>	Almost cosmopolitan.
	<i>Setaria verticillata.</i>	Temp. and trop. regions.
	<i>Phragmites karka.</i>	Almost throughout tropics of Old World.

Family	Species	Remarks Regarding Distribution
Gramin.	... <i>Diplachne fusca</i> . <i>Chloris barbata</i> . <i>Eleusine aegyptiaca</i> . <i>Oryza coarctata</i> .	Tropics of Old World. Tropics generally. Warm regions of Old World. Only Indian.

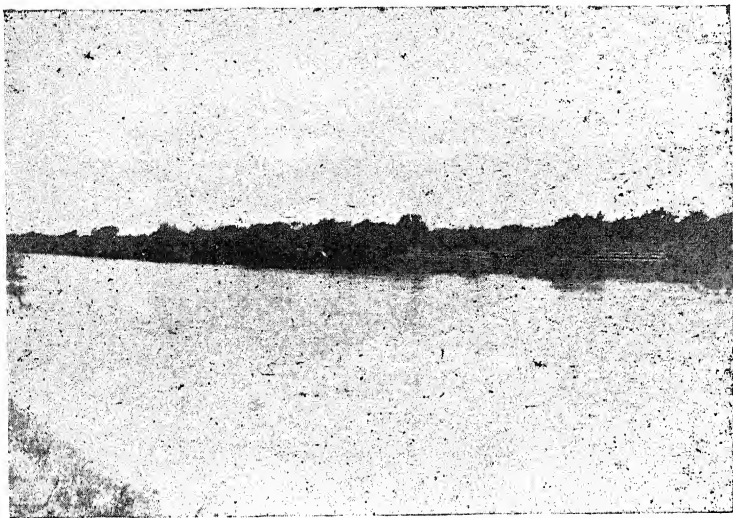
These 48 species occurring in both deltas belong to 26 families. A glance at the notes on distribution shows that all, with the exception of *Ceriops Roxburghiana*, *Daemia extensa*, *Crinum asiaticum*, *Pandanus tectorius* and *Oryza coarctata*, have a very wide distribution.

If we consider the habit of the plants i.e. whether they are herbs, undershrubs, shrubs or trees, we arrive at the following results which we also represent graphically :

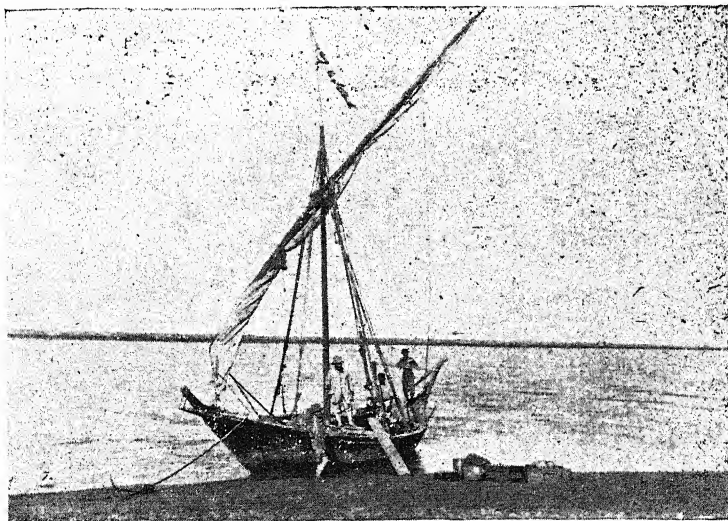
	Indus Delta		Sundribuns	
	Absolute number	% in round numbers	Absolute number	% in round numbers
H.	179	65	156	51
U.	26	9	22	7
S.	40	14	60	20
T.	34	12	66	22
Total	279	100	304	100



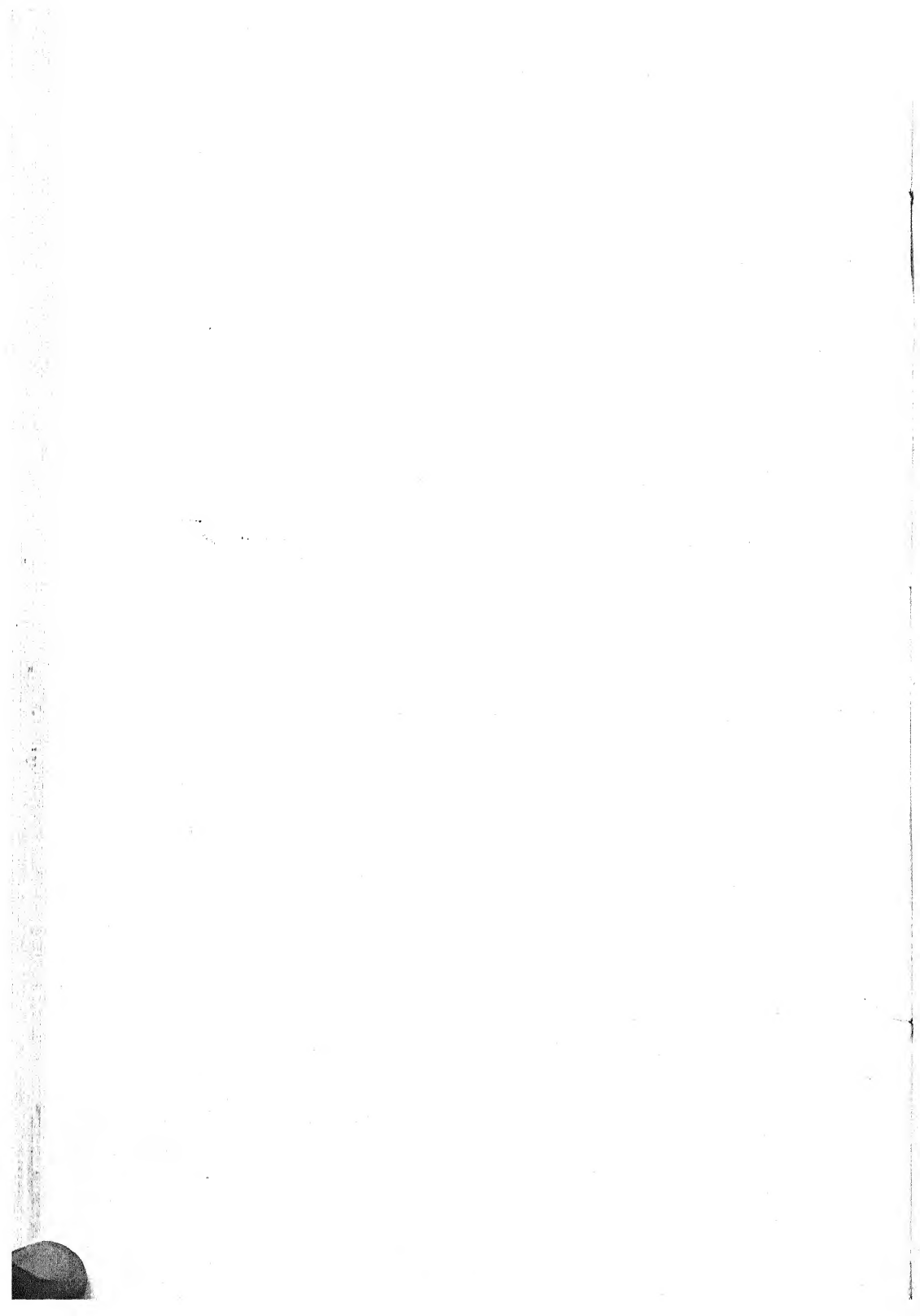
Graph 16.—The relative prevalence of herbs (H), undershrubs (U) shrubs (S) and trees (T) in the two areas.



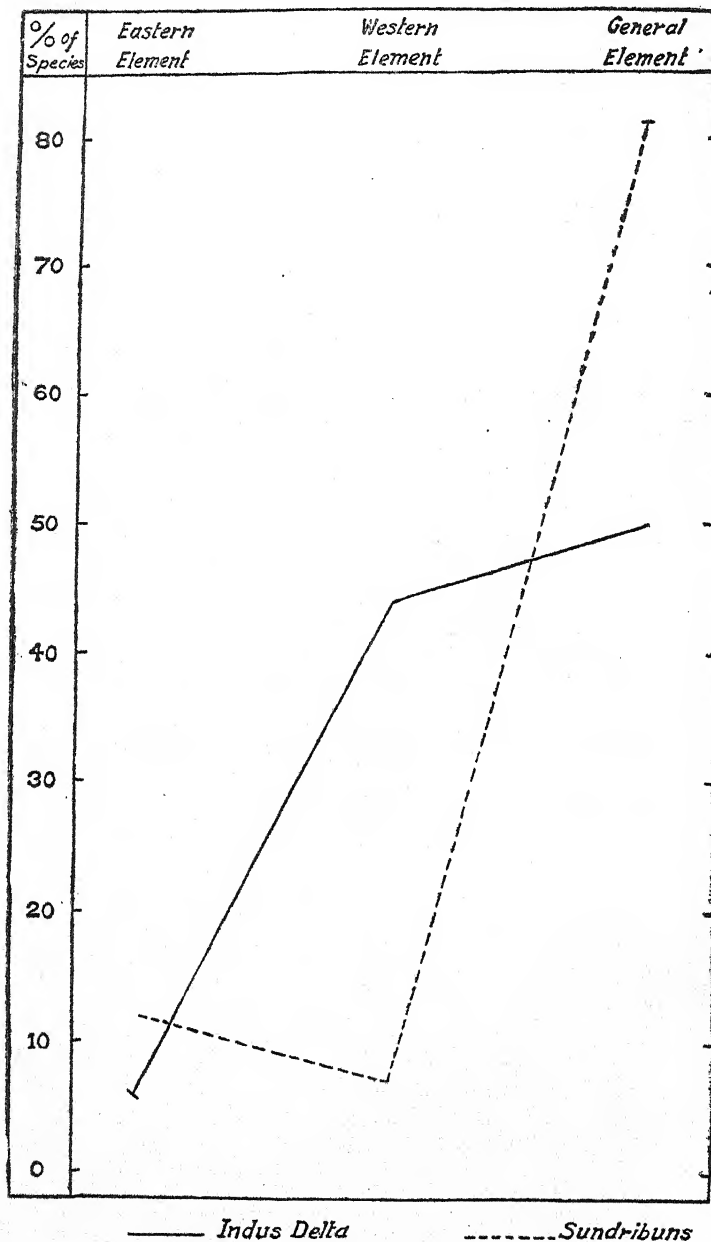
No. 39. Bughar Canal not far from Mirpur Sakro. *Saccharum
Rovanne* Linn., low shrubs of *Tamarix dioica*, and *Acacia arabica*.



No. 40. On the Indus below Ketī Bandar. In front of the loat,
Oryza coarctata.



We show the same relations between the two areas graphically.



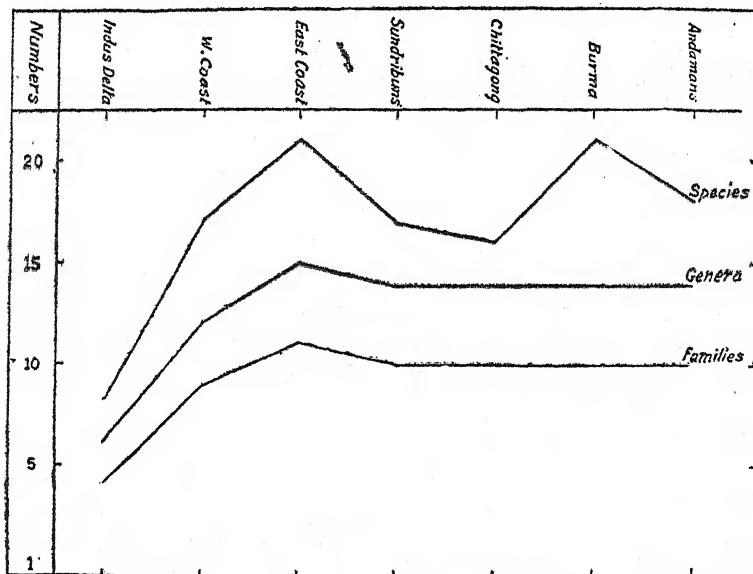
Graph 17.—Geographical distribution of the vegetation of the Indus Delta and the Sundribuns.

The purely E. element is small in both, whilst the Indus Delta receives a distinct character from the W. element.

There is one important class of plants, the so-called Mangroves, which we should like to consider separately. Many data of the following list are taken from Troup, Silviculture of Indian Trees, the rest from Gamble's and Haines' Floras.

Family.	Species.	Indus Delta.	W. Coast.	E. Coast.	Sundribuns.	Chittagong.	Burma.	Andamans.
Rhizophor. ...	<i>Rhizophora mucronata</i> Lam.	...	*	*	*	*	*	*
	„ <i>conjugata</i> Linn.	...	*	*	*	...	*	*
	<i>Ceriops Candolleana</i> Arn.	...	*	*	...	*	...	*
	„ <i>Roxburghiana</i> Arn.	...	*	*	*	*	*	...
	<i>Khandelia Rheedei</i> W. & A.	...	*	*	*	*	*	*
	<i>Bruguiera gymnorrhiza</i> Lam.	...	*	*	*	*	*	*
	„ <i>eriopetala</i> W. & A.	...	...	*	*	...	...	...
	„ <i>caryophylloides</i> Bl.	...	...	*	*	...	*	...
Meliac. ...	„ <i>parviflora</i> W. & A.	...	...	...	...	...	*	...
	<i>Carapa obovata</i> Bl.	...	...	*	*	*	*	*
Leguminos. ...	„ <i>moluccensis</i> Lam.	...	...	...	*	...	*	*
	<i>Cynometra ramiflora</i> Linn.	...	...	*	*	*	*	*
Combretac. ...	<i>Lumnitzera racemosa</i> Willd.	...	...	*	*	*	*	*
	„ <i>coccinea</i> W. & A.	...	...	...	...	...	*	*
Lythrac. ...	<i>Sonneratia acida</i> Linn. f.	...	*	*	*	*	*	*
	„ <i>apetala</i> Ham.	...	...	...	*	*	*	*
	„ <i>alba</i> Sm.	...	...	*	...	...	*	...
	„ <i>Griffithii</i> Kurz.	...	...	...	...	...	*	...
Rubiace. ...	<i>Scyphiphora hydrophyllacea</i> Gaertn.	...	...	...	*	...	...	*
	<i>Aegiceras majus</i> Gaertn.	...	*	*	*	*	*	*
Acanthac. ...	<i>Acanthus ilicifolius</i> Linn.	...	...	*	*	*	*	...
Verbenac. ...	<i>Avicennia officinalis</i> Linn.	...	*	*	*	*	*	*
	„ <i>alba</i> BC.	...	...	...	*	...	...	...
	„ <i>marina</i> Vierh.	...	...	...	*	...	...	...
Euphorbiac. ...	<i>Excoecaria agallocha</i> Linn.	...	...	*	*	*	*	*
Palmae ...	<i>Nipa fruticans</i> Wurm.	...	...	...	*	*	*	*
	<i>Phoenix paludosa</i> Roxb.	...	...	*	*	*	*	*
		8	17	21	17	16	21	18

The subjoined graph gives the number of species, genera and families observed in the various regions.



Graph 18.—Distribution of the families, genera and species of the Mangrove-group in the Indo-Burmese region.

The fact that from the Indus Delta only 8 species of Mangroves are recorded, whilst all the other regions are represented by 16—21 species, confirm our suspicion that we have overlooked quite a number of plants in the lower part of the Delta. Sea-sickness, heat, hunger, and thirst had produced that feeling in us under whose influence even enthusiastic men lose all scientific interest.

(To be continued.)

NOTICE

The following letter has been received by the Editor:—

BRITISH EMPIRE VEGETATION COMMITTEE

(appointed by the Imperial Botanical Conference, London, 1924)

Chairman : Professor A. G. TANSLEY, F. R. S.

Secretary : Dr. T. F. CHIPP, Royal Gardens, Kew, England,
to whom all contributions and communications should be addressed.

BRITISH EMPIRE VEGETATION ABSTRACTS.

Kew,
July, 1928.

DEAR SIR,

In connection with the Scheme for Abstracts, a notification of which has been sent to you, my Committee request that Authors may be asked to send me at this address a **separate copy of every paper** dealing with the vegetation of the Empire Overseas, of which an abstract is desired. This may take the form either of a press proof or of a finished separate when these are printed, but it is desirable for the smooth and punctual working of the scheme that all separates should be in my hands as early as possible.

Yours faithfully,

T. F. CHIPP,
Secretary.

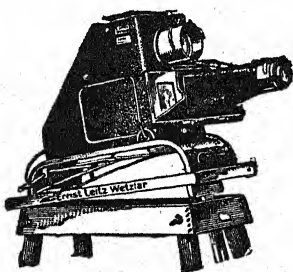
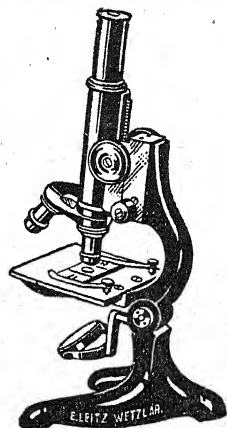
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The Journal of the Indian Botanical Society.

(Formerly "The Journal of Indian Botany.")

VOL. VII.

DECEMBER, 1928.

Nos. 3 & 4.

NOTES ON THE TERATOLOGY OF CERTAIN ANGIOSPERMS¹

BY T. C. N. SINGH,

Microscopist, Cotton Research Laboratory, Lyallpur (Punjab)

AND B. N. SINHA,

Assistant Director of Agriculture, Sepaya (Bihar).

The present work was started and nearly finished at the Botany Department of the Lucknow University, but was brought out in the present completed form at the Cotton Research Laboratory, Lyallpur. The plants alluded to in this note were all found growing at Lucknow either wild or cultivated. They include members belonging to such diverse families as the Nyctaginaceae, Polemoniaceae, Solanaceae, Cucurbitaceae and Compositae. The observations recorded in this note are a result of casual observations made from time to time and an attempt has been made in the following pages to describe the abnormalities as they appear, avoiding any fanciful discussions which may lead to erroneous conclusions.

Boerhaavia repanda Willd.

This member of the family Nyctaginaceae is a perennial weed growing very extensively on waste land or barren fields, specially during the rainy season. It is particularly interesting, because it shows anomalous features in the anatomy of its root, stem and leaf.² That such a plant should show some external monstrosity also, is rather significant. An abnormal leaf has come to our notice which

¹ Singh, T. C. N. and Sinha, B. N.: (Abstract) A note on the teratology of certain Angiosperms. *Proc. Indian Sci. Congress*, Calcutta meeting, Jan. (1928).

² Mukerji, S. K. and Singh, T. C. N.: (Abstract) The study of five representative Lucknow plants of the hot season with a view to find out the nature of the adaptation of these plants to the marked periodic climate. *Ind. Bot. Soc.*, Lucknow meeting, Jan. 1923 *Journ. Ind. Bot. Soc.*, Vol. III, p. 262.

is fasciated. It is bilobed (Plate II, Fig. 8), each lobe having its own midrib and side veins but with a single common petiole possessed of a median groove. Thus, it is evident that this fasciated specimen, is a homologue of two leaves.

Phlox Drummondii ¹

The records of abnormalities in the species of the genus *Phlox*, other than *P. Drummondii* refer to the leaf enation in *P. paniculata* (*decussata*)² and to heteromery in *P. subulata*³ and a few other cases.

Phlox Drummondii is a very common garden plant represented by several varieties. Over a thousand flowers of the said species were examined—from plants growing in the Botanic Garden of the Lucknow University—of which surprisingly enough, about one per cent showed a fairly wide variation in their floral parts, specially in the Calyx K₍₄₋₆₎, Corolla C₍₃₋₆₎ and Androecium A₍₅₋₆₎ (epipetalous), while the normal floral formula for the family Polemoniaceae ⁴ in

which *Phlox* is included, is represented by $\overbrace{K_{(5)} C_{(5)} A_5 G_{(2-5)}}$

The occurrence of hexamery in the three outer whorls associated with the production of four carpels in *P. Drummondii* was shown by Wydler⁵ about three-quarters of a century ago, but our hexamerous specimens differ from those of his, in their gynæcia which are composed in every case of only three carpels. For the sake of clearness the number of floral parts of the typical abnormal flowers is tabulated below (see also Plate 1, Figs. 1-4).

Type No.	Calyx	Corolla	Androecium	Gynæcium
1	5	3	3	(3)
2	4	4	4	(4)
3	5	5	4 or 5 or 6	(3) or (4)
4	6	6	6 or 5	(4)
5	6	6	6	(3)

¹ For figure of the plant see Nicholson, G. The Illustrated Dictionary of Gardening, Vol. III, p. 100, Fig. 112.

² Worsdell, W. C.: (1915) The Principles of Plant Teratology Vol. I, pp. 198, 201; Vol. II, pp. 162, 200.

³ Vuillemin, Paul: (1909) L'hétéromerie normale du *Phlox subulata*. *Compt. Rend. Paris*, CXLXIII, p. 650.

⁴ Willis, J. C.: (1919) Flowering Plants and Ferns, pp. 526, xlv.

⁵ Wydler, Flora (1857) p. 29 and (1860), p. 657

The interest centres round the plasticity of the flowers in this species. That such a wide range of variation should occur is rather striking. It is perhaps due to chorosis or suppression or both, resulting in an increase or decrease of the floral parts.

Datura Metel L.

Datura Metel L.—a member of the family Solanaceae—is quite a common plant growing throughout India, and flowers usually during the months from August to March. The floral parts are typical of the family¹ namely $K_{(5)} \overset{\text{C}_{(5)}}{\text{A}_5} G_{(2)}$ but sometimes the number of the sepals, petals and stamens may be increased by one *i.e.* then the calyx, corolla and androecium consist of six members each instead of the usual five, the gynæcium being quite normal (Plate 1, Fig. 5). Jaeger² as early as 1814 observed in *Datura fastuosa* L., the occurrence of an anther with a forked apex, besides the four normal ones. His observation is of value in so far that it points to a possible explanation of the sporadic occurrence of an extra sixth stamen (in *Datura Metel*) which may very likely be due to a complete chorosis of one of the stamens, Jaeger's case perhaps representing the first stage in chorosis. At the same time it is interesting to note that all the stamens (including even the extra 6th) are so similar, both in the internal and external morphology of their anthers and their corresponding filaments that any discrimination between them is impossible. The increased number of calyx and corolla may also be explained similarly.

Increase in the number of parts in the calyx, corolla and androecium is known³ in *Datura Stramonium* also, but in every such case it is curious that the gynæcia are either tri-carpellary or tetra-carpellary (but mostly tri-carpellary). However, this is not so in our specimens which are quite normal so far as the gynæcia (bi-carpellary) are concerned.

Trichosanthes dioica Roxb.

Trichosanthes dioica is the common Parwal, the fruit of which is eaten as a vegetable. The only case of abnormality known to us refers to the occurrence of fertile stamens in the female flowers⁴ but no teratological observations are recorded at least in the case of fruits. Normally the fruits are spindle-shaped but sometimes two such fruits appear to have fused together with each other and all stages from partial to complete fusion may be noticeable (see Plate I, Figs. 6-7). Moreover it is interesting to find that sections through such a fasciated

¹ Willis, J. C. *loc. cit.* pp. 611, xlv.

² Jaeger, G.F.: (1814) Ueber die Missbildungen der Gewächse, Stuttgart, p. 115.

³ Blakeslee, A. F., Morrison, G. and Avery, A. G.: (1927) Mutations in a haploid *Datura*. *Journ. of Heredity* Vol. 18, No. 5, pp. 195-6.

⁴ Baillon: (1922) Occurrence of fertile stamens in female flowers in *Trichosanthes*. *Bull. Period. de la Soc. Linn. de Paris*, p. 308.

fruit (a homologue of two) show that each part is composed of three carpels, being a complete homologue of a normal Cucurbitaceous gynoecium. Thus it seems quite clear that such a condition has resulted from fasciated double flowers which may be occurring in nature along with the normal ones.

Cosmos bipinnatus ^{1, 2}

The phenomenon of fasciation of capitula is extraordinarily common among the Compositae but no such record has so far been made for the genus *Cosmos*. The case in question (Plate II, Fig. 9) has its main peduncle very much flattened, looking as if it is due to the concrescence of a number of capitular peduncles. Right at its apex, the flattened structure is shortly forked into two, each being surmounted by a fasciated capitulum which is a homologue of at least two capitula. The two capitula are situated so close together that when cursorily examined they look like a single flattened capitulum. A little below the main fasciated peduncle occur about a dozen and a half normal peduncles (with the exception of one) arranged in a whorl each bearing a head at its apex. One of them (Plate II, Fig. 9 A) situated between the main flattened peduncle and the bundle of peduncles tied up together on the extreme left in the photograph, is also fasciated, as is evident from the flattened condition of its peduncle and the rather biggish head.

Helianthus annuus L.

In this plant the abnormalities are known in the vegetative organs ³ but recently an abnormal capitulum has come to our notice in which seven green 'leaf'-like structures looking like involucre bracts are seen jutting out of the central region of the disc (Plate II, Fig. 10) on which a number of disc and ray florets are set in the normal manner. On close examination it has been found that these "involucre"-like organs are altogether leafy except for a little thickening at the base and further, curiously enough, each of them is borne in the axil of a chaffy bract (Plate II, Fig. 11) like the other normal florets. Thus it is quite clear that the "leaf"-like structures are of shoot nature, hence homologous to the normal florets, the thickened portions at their base perhaps representing the vestige of an aborted flower. Therefore it is concluded that they are homologous to the habitually nearly abortive sepals (so common among the Compositae) which have—through some physiological circumstance—become leafy and the corresponding flowers bearing them have aborted.

¹ We have very great pleasure in according our hearty thanks to Miss L. Baksh, M. Sc. for kindly providing us the specimen obtained from the Isabella Thoburn College Garden, Lucknow.

² For figure Nicholson, G. *loc. cit.* Vol. I, p. 386, fig. 534.

³ Worsdell, W. C. *loc. cit.* Vol. I, pp. 82, 215.

Summary.

Descriptions are here given of abnormalities observed in half-a-dozen angiospermous plants.

(1) In *Boerhaavia repanda* Willd., a case of a fasciated leaf (a homologue of two leaves) is described.

(2) *Phlox Drummondii*: notes on the variation in its floral parts are made.

(3) In *Datura Metel* L. hexamery is recorded.

(4) Fasciation of fruits (a homologue of two) is described in *Trichosanthes dioica*. It is interesting to note that each part of the fasciated fruit is tri-carpellary, being a complete homologue of a normal Cucurbitaceous gynoecium.

(5) In *Cosmos bipinnatus* fasciation of capitula is noted.

(6) Very interesting is the case of an abnormal capitulum of *Helianthus annuus* L. in which seven "leaf"-like structures looking like involucre bracts (arising from the central region on the disc), are each borne in the axil of a chaffy bract. They have been regarded as homologous to the habitually nearly abortive sepals which have through some physiological circumstance become leafy and the corresponding flowers bearing them have aborted.

Acknowledgements.

Our sincere thanks are due to Dr. S. P. Agharkar for his kindly interest in informing us about the literature available at Calcutta; and to Prof. B. Sahni for his kindly reading through the manuscript and his criticisms.

LYALLPUR

15th May, 1928.

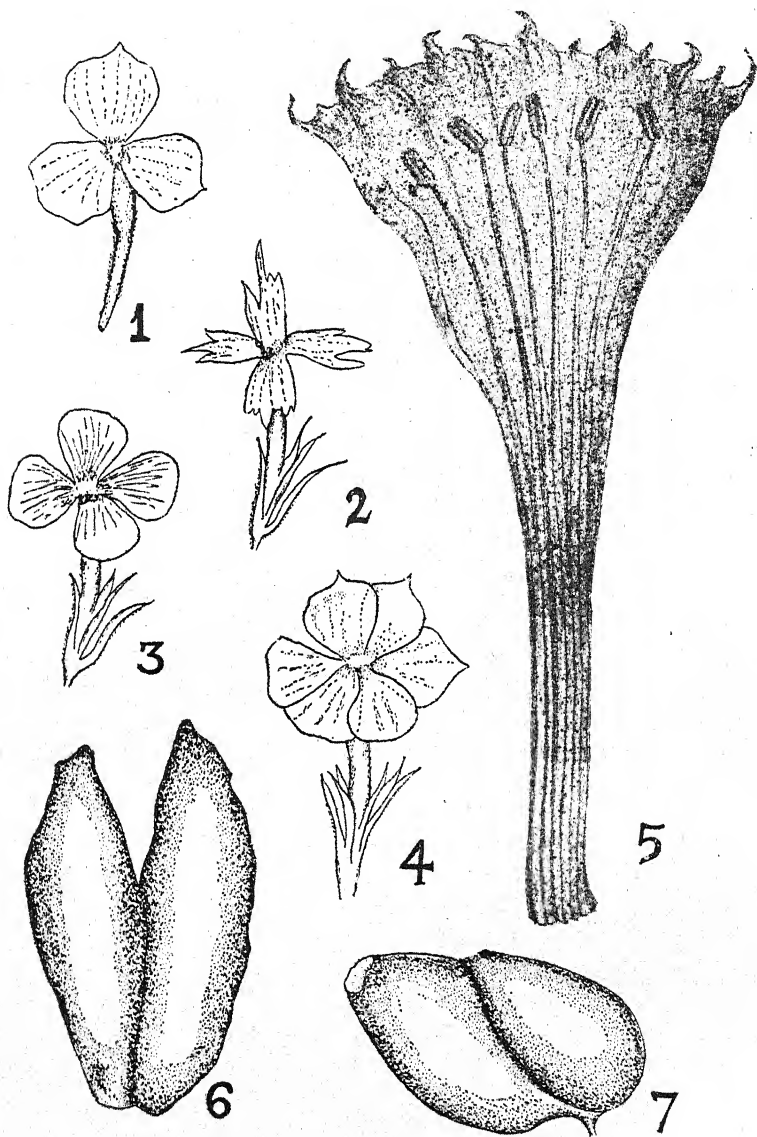
Explanation of Plates.

PLATE I.

- Figs. 1—4. Abnormal flowers of *Phlox Drummondii*. $\times 4/5$.
 Fig. 5. A flower of *Datura Metel* L. split open on one side to show the disposition of the six stamens. $\times 4/5$.
 Figs. 6—7. Fasciated fruits of *Trichosanthes dioica* Roxb. $\times 4/5$.
 Fig. 6 shows the partial fusion of two fruits.

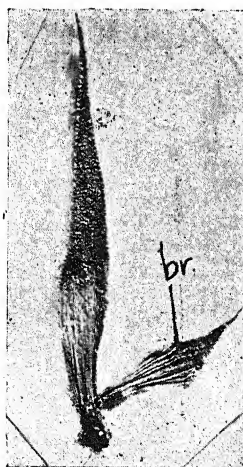
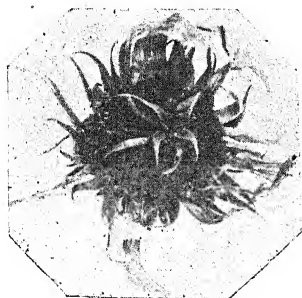
PLATE II.

- Fig. 8. *Boerhaavia repanda* Willd.: A fasciated leaf. Nat. size
 Fig. 9. *Cosmos bipinnatus*: Fasciated capitula. $\times 3/4$.
 Fig. 10. *Helianthus annuus* L.: An abnormal capitulum showing the seven "leaf"-like structures in the central region of the inflorescence. Nat. size.
 Fig. 11. *Helianthus annuus* L.: One of the leaf-like structures borne in the axil of a chaffy bract. (br. = bract) \times about 8.



B.N.S. del.

Plate I.



10

11

T.C.N.S. phot.

Plate II.

CONTRIBUTIONS TO OUR KNOWLEDGE OF THE LIFE-HISTORY OF *PINUS LONGIFOLIA*

BY M. L. SETHI, M.Sc.,

Lecturer in Botany, Government College, Lahore.

CONTENTS.

Contributions to our Knowledge of the Life-history of *Pinus longifolia*.

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VI. Notes on Abnormal Female Prothalli	138
VII. Abnormalities in the male cone-bearing shoots	141
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I. Introduction.

The cytology of some foreign species of *Pinus* has been worked out but so far no Indian (Asiatic) species of the genus has been the subject of such study. It was therefore thought desirable to investigate the cytological life-history of an Indian species and the writer, acting on a suggestion of Prof. Kashyap, began this work in the winter of 1919-20.

There are four or five species of the genus *Pinus* which are found in India, viz. *Pinus excelsa*, *P. Gerardiana*, *P. Khasya*, *P. longifolia*. Of these four the last one is found at the lowest altitudes in the Himalayas (2,000-5,000 ft.) as compared with the other species. It is also very often cultivated in the Panjab plains, especially in gardens. As it is common in Lahore it was decided to investigate this species.

The present studies were carried out in the Botanical Laboratory of the Government College, Lahore, and the writer wishes to express here his best thanks to Prof. Kashyap for kind interest in the work and many helpful suggestions and criticisms.

II. Material and Methods.

The collection of material was begun in Jan. 1920 and was continued up to Jan. 1927 excepting the winter of 1923-24 when the writer was away from Lahore. Collections were made once a week or oftener. For following fertilization stages and the reduction divisions in the pollen-mother cells collections had to be made daily or twice a day. The material was taken from trees in the various gardens of Lahore, viz., the Gol Bagh, the Botanical Garden of the Government College and the Lawrence Gardens. It was fixed immediately after removal from the tree. One collection of material was made near Chamba (Lat. $32^{\circ} 29' N.$, Long. $76^{\circ} 10' E.$, Alt. 3,027 ft. above sea-level) in the Himalayas in the month of July 1920 and it proved very fruitful. Another collection was made from a tree in the Royal Botanic Gardens, Calcutta, in February 1921, for which the writer is indebted to the Curator.

At first the following first two fixatives were used. Later on the third one, which had been used by Miss Ferguson (24) for *Pinus* species, was used :—

I.	Chromic Acid	...	...	3 grms.
	Glacial Acetic Acid	...	...	3 c.c.
	Distilled water	...	...	100 c.c.
II.	Corrosive Sublimate	...	...	3 grms.
	Glacial Acetic Acid	...	...	3 c.c.
	Alcohol 70%	...	...	100 c.c.
III.	Chromic Acid	...	...	1.3 grms
	Osmic Acid	...	...	0.5 gm.
	Glacial Acetic Acid	...	...	8.3 c.c.
	Distilled water	...	...	160 c.c.

The following stains were tried at first :—Flemming's triple stain, Iron-alum Haematoxylin, Diamant Fuchsin and Light Green, and Gentian Violet and Orange G. Later on the Diamant Fuchsin and Light Green combination was dropped and only the others were used.

Since ovules in the second year of their growth in *P. longifolia* are pretty large their infiltration with paraffin offered great difficulty. They had to be kept in the paraffin-bath for three weeks continuously before they could be sectioned. Sections were cut 5 to 10 microns in thickness.

III. General Observations.

Pinus longifolia is not only the most easily accessible species of *Pinus* down in the plains of the Panjab because of its cultivation in the gardens but it is also the only species in the outer Himalayas at certain altitudes. The main upright trunk of the tree gives off several

tiers of branches. The habit is indicated in plate I fig. 1. The lower branches bear only the male cones and it seems that at first a young tree produces only male cones. Only the topmost branches and occasionally the lower branches give rise to shoots which bear the female cones. The branches are thus strictly male or female unlike the case well known in *P. silvestris*. On a male branch one can easily count thirteen years' growth externally. The remains of the whorls of scales which protect the young male cones at successive intervals indicate the growth of successive years. Similarly on a female branch one can easily see the cones of four successive generations attached to the branch (plate I fig. 2). It is rarely in the lower branches but not so rarely in the upper branches that male shoots are given off by the female ones.

In Lahore, the male cones are initiated in September. They grow slowly but continuously till pollen is shed in February. During the first week of February the male cones elongate considerably and in the second and third week of that month begin to discharge their pollen.

The female cones are initiated in January and become visible in February at the ends of the youngest female shoots. Generally two or three female cones are produced by a shoot but sometimes as many as five may be produced. The cones are reddish green in colour and open at first. The bract-scales are larger in size and more prominent than the ovuliferous scales at this time. After pollination, which takes place during the latter half of February, the ovuliferous scales grow more vigorously than the bract-scales and consequently the cones close up. Strasburger (67) stated in 1887 that 'after full pollination the fruit-scales close together again by their edges and are glued together by resin'. This statement was modified in 1900 (69) into: 'After full pollination the fruit-scales soon close together, and these are consolidated by the inter-growth of papillae'. The last statement stands as such in the 1924 edition (70) of Strasburger's book. In *Pinus longifolia* no papillae can be made out. The closure is simply due to the rapid growth of the ovuliferous scales. This growth is more rapid on the dorsal than on the ventral surface.

The safety of the pollen-grains within the pollen-chamber of the ovules is secured exactly in the same way as described by Ferguson (24) for *Pinus* species and by Ottley (54) for *Juniperus communis*.

The female cones even after pollination keep on growing till they become about an inch in length. After this their growth is stopped in May and they rest. In the resting condition the cones become brown externally.

The writer's observations fully support the statement of Ferguson (24): 'The evidence is conclusive that the ovules are not organized

in the species of Pines studied by the writer until about three weeks or less before pollination'.

New foliage leaves come out in March and April in Lahore. The male branches produce the dwarf shoots just after producing the male cones and therefore above them. The female branches produce the dwarf shoots first and then the female cones. Therefore the dwarf shoots on the female branches are below the female cones produced in the same year.

Although a very large number of cones from a fairly large number of trees have been studied no bisporangiate cones were met with as reported by Steil (65) for *P. montana* and by Goebel (30) for *P. maritima*.

IV. Development of female prothallus, fertilization and embryo formation.

Female Cone and Megaspore-Mother-Cell.

As stated above, the female cones are initiated in Lahore in January. By the middle of February ovules show the integument and the nucellus. In the latter a deep-seated megaspore-mother-cell was seen on February 18, 20 and 22 in 1921. This megaspore-mother-cell is always more or less conical, the broader end being invariably towards the chalaza. The walls of this cell are very delicate. The cytoplasm is very finely granular and shows here and there a vacuole. The nucleus of the megaspore-mother-cell in the earliest stages is only slightly larger than the nuclei of the surrounding nucellar cells. The nucleus evidently grows and so does the cell as a whole. Ultimately the diameter of the nucleus becomes twice as large as that of the nuclei of the neighbouring nucellar cells, when the first heterotypic division takes place.

The nucleus of the resting megaspore-mother-cell does not stain so deeply as its neighbours (plate II fig. 3). The reticulum is very faint and the chromatin granules very small. It is only during the early prophase of the heterotypic division that there is an appreciable increase in the staining reaction of the nucleus.

The megaspore-mother-cell may continue to grow for three weeks. Fig. 5 represents it on February 18, while fig. 6 shows the stage of the nucleus which obtains on March 5. Both the figures have been equally magnified so that the increase in the size of the nucleus can be easily visualized.

This megaspore mother cell undergoes a reduction division. Plate II fig. 4 shows the nucleus of the megaspore-mother-cell during prophase when the chromatic material has organized itself into a spireme. Plate II fig. 5 represents the same undergoing the first

contraction. Plate II figs. 6 and 7 represent still later stages when the bivalent chromosomes are being formed. Other stages were not observed but it may be assumed that a linear tetrad is formed. A spongy tissue differentiates about the megaspore-mother-cell when the latter enters upon the first heterotypic division.

Only a few free nuclei are formed by the division of the megaspore nucleus before the resting period begins in May. The number of these free nuclei is never so large as 32 as Ferguson found in some cases but she states, 'the number may not be fixed in the same species, but it is certain that it is never very large' (24).

Growth in the female cones of the previous year is resumed every year in the month of February. The new parts of the ovuliferous scales formed after the resumption of this growth are green. Thus the apical brown region of each ovuliferous scale is carried up and represents the previous year's growth.

The endosperm develops vigorously, but till the last week of March only a peripheral layer of cytoplasm with free nuclei can be seen. Development seems more rapid in April, and by the middle of this month the endosperm is fully matured.

It is needless to mention the gradual transition from the free nuclear state of the endosperm to the fully formed female prothallus. No disparity is met with in *P. longifolia* in this regard when compared with the species worked out by Ferguson (24). Neither has the writer made an attempt to count the number of free nuclei which are formed before wall-formation sets in, this being particularly difficult in *P. longifolia* because of the very large size of the embryosac. The latter is about 8 mm. in length when wall-formation sets in.

External Morphology of Female Prothallus.

When mature the female prothallus is a colourless cylindrical body slightly tapering towards the two ends. It measures from 11 to 12 mm. in length. It is slightly compressed from the abaxial and the adaxial sides. The longer and shorter diameters are approximately 2.6 and 2.3 mm. respectively. At this time the glandular cells of the spongy tissue surrounding the prothallus which are so conspicuous in the early stages, were much reduced. Close to the micropylar end their crushed remains only could be seen, while at and close to the chalazal end the cells still persisted. The prothallus is externally bounded by the megaspore membrane which is quite conspicuous. This membrane is equally thick all round the prothallus except towards the micropylar end where it gradually becomes thin.

Thomson (74) who has made an extensive study of the megaspore membrane in five genera of the Abietineae states 'that in this group the coat is thick in the chalazal region, and thins out gradually towards

the micropylar portion of the prothallium being not more than one-third as thick at the apex as at the base of the megaspore.' Lawson (39) for *Pseudotsuga* and Miyake and Yasui (47) for *Pseudolarix* have made similar statements.

Internal Morphology of Female Prothallus.

The prothallus is made up of thin-walled polygonal parenchymatous cells which are compactly arranged. Two or three layers of cells towards the periphery are smaller than the cells towards the central region. The cells are uninucleate, contain very little protoplasm and very large vacuoles. No binucleate or multinucleate cells could be seen. The cells do not contain any starch granules at this stage. Later on the cells of the central region surrounding the growing embryo become very rich in starch.

Only the micropylar end of the prothallus bears the archegonia. The number of archegonia ranges between 2 and 7; 3, 4 and 5 being the commonest numbers. The fertile end bearing the archegonia may be occasionally slightly constricted off from the rest of the prothallus. The archegonium is about one mm. in length. Its external shape and diameter depend upon the number of archegonia borne by the prothallus; if they are numerous they are narrow; if few they are broad. They are visible to the naked eye as opaque white oval bodies aggregated around the micropylar end. The longer axes of the archegonia are almost parallel to the longer axis of the prothallus or the necks of the archegonia may make acute angles with the longer axis of the prothallus. The archegonia have more or less deep archegonial chambers. Each archegonium has a neck usually consisting of eight cells in two tiers with four cells in each tier. In rare cases the archegonial neck consists of four cells only in a single tier at the mature stage. Ferguson (24) writing about the necks of the 5 species of pines which she studied states, 'In *P. Strobus* the typical neck of the archegonium consists of 4 cells, all lying in the same plane, while in *P. austriaca* and *P. rigida* it is made up of 8, disposed in two layers of 4 cells each, but there is a lack of uniformity both in the number and in the arrangement of these cells, not only in different but in the same species.'

All the archegonia have their necks opening towards the micropyle. Each archegonium is surrounded externally by its own layer of jacket cells characterized by large nuclei and specially granular cytoplasm. When the number of archegonia is small, the parenchymatous cells of the prothallus fill in the space between the jacket cells of the different archegonia, but when the number of archegonia is large, the jacket cells of adjacent archegonia are in contact with one another and there are no filling parenchymatous cells of the prothallus.

In some cases, though rarely, one finds two adjacent archegonia having a single layer of jacket cells in common between them for some distance. In describing the jacket layer of the archegonium in *Pseudolarix*, Miyake and Yasui (47) make a very similar statement. 'As in other *Abietineae* the archegonia are arranged quite separate from one another, and they may come in contact in the middle region where they are widest. Even there the egg-cells never come into direct contact as in the *Cupressineae* and some of the *Taxodineae* but they are always separated by one or two layers of jacket cells.' Doyle (19) describes an identical thing taking place in *Larix leptolepis*.

The Development of the Archegonium.

Generally the archegonial initials can be located when the prothallus shows a continuous tissue. This happens in the first week of April in Lahore. Near the micropylar end the cells of the prothallus are cylindrical with their longer axes parallel to the longer axis of the ovule. Later on the nuclei of some of these cells become larger than those of their neighbours. Such cells ultimately become the archegonial initials (plate II fig. 8).

The archegonial initial seems to grow rapidly in size. The nucleus at first occupies a central position but it soon moves towards the micropylar end of the cell (plate II fig. 9). After reaching this place the nucleus undergoes a mitotic division and the resultant two cells are the primary neck cell and the central cell (plate II fig. 10). The primary neck cell undergoes three repeated divisions and so forms 8 cells of the neck in 2 tiers of 4 cells each. The cells of the prothallus surrounding the developing archegonium near the apical region grow more vigorously than the former and so an archegonial chamber is formed. The central cell increases in size very rapidly and its nucleus lies just below the neck (plate V fig. 11 and plate III fig. 13). This sequence of development agrees closely with that described for other species of *Pinus* by Ferguson (23, 24).

The layer of jacket cells which invests each archegonium is not distinguishable till about the 14th of April *i.e.*, about 8 days after the initials are seen.

The Cutting off of the Ventral Canal Cell.

While lying just below the neck the nucleus of the central cell initiates the mitotic division which produces the egg-cell and the ventral canal cell (plate II fig. 12). This event took place on the 21st of April in Lahore in 1922. In the 1921 collection this division was observed on the 29th April. Some archegonia of this collection showed the maturation of the egg nucleus. Before division the diameter of the central nucleus measures about 54 microns. It contains one big nucleolus and two or three smaller nucleoli. The

bigger one occupies a central position while the smaller ones are peripheral. As the central nucleus prepares for division the cytoplasm of the egg becomes much more granular although the vacuoles in it are as numerous and prominent as before. The nucleoli disappear and the chromatin condenses at various places on the net-work. The spindle is formed wholly within the nucleus. It is bluntly pointed at the two poles but appears very broad if the sections do not pass through its median plane (plate II fig. 12). The chromosomes when they are orientated at the equator of the spindle are U or V shaped and not straight as Blackman (3) found in *P. silvestris*. This is not so important as chromosomes are known to undergo slight changes of shape at different periods in the same species. The equator of the spindle in the earlier stages of the division lies exactly between the two daughter nuclei and is straight. Later on it becomes concave on the side of the ventral canal nucleus (plate III fig. 14). A similar figure has been given by Chamberlain (7).

The Ventral Canal Cell.

The chromosomes which go to form the ventral canal cell do not round off after collecting at the pole but become aggregated in a more or less flat plate as seen in (plate III fig. 14). They do not undergo the typical telophasic changes which ordinarily result in a resting nucleus. The cell-plate is laid down and a fragile transverse wall is formed between the daughter cells. No nuclear membrane is formed around the ventral canal nucleus and it shows signs of disorganization from its very inception. The behaviour of the central nucleus during the cutting of the ventral canal cell agrees very closely with that described for *Pinus* species by Ferguson (24), for *P. silvestris* by Blackman (3), and for *Picea excelsa* by Miyake (46). Chamberlain (7), however, states that a nuclear membrane is formed around the ventral canal nucleus. The ventral canal cell is liable to split off from the egg cytoplasm in the region of the equator of the spindle and is generally to be seen as a mass of deeply staining substance with a little cytoplasm on the egg side of it. It persists sometimes till the fertilization time which occurs one week after the division of the central cell.

Although a fairly large number of ovules have been sectioned and a large number of ventral canal cells studied, in no case did the writer find it equal in size to the egg nucleus as reported by Chamberlain (7).

Maturation of the Egg Nucleus.

While the ventral canal nucleus shows signs of disorganization very early, the egg nucleus begins to grow in size very soon. It begins to travel down towards the centre of the egg (plate V fig. 15). It may be seen travelling down while the fibres of the spindle of the

previous division have not as yet disappeared. The longer diameter of the nucleus before the commencement of this downward movement is about 18 microns but only a short distance below it measures 32 microns. Still lower it measures 90 microns and when it has reached the centre of the egg it attains the enormous longer diameter of 202.5 microns (plate V fig. 16). It is ovoid in shape at this stage. It shows a tangle of fine threads to which are anchored numerous small rounded vesicles. No vacuoles are to be seen in the egg cytoplasm at this time. The cytoplasm becomes much more granular than before and the granules are bigger in size. Proteid vacuoles make their appearance in the cytoplasm and they look like ordinary nuclei. Each one of these shows a fairly large deeply staining body lying in the centre and a peripheral lightly staining area bounded by a definite wall-like structure where it comes into contact with the cytoplasm. This can be made out in (plate V fig. 16). A similar structure of the proteid vacuole is described for *Picea excelsa* by Miyake (46). He states, 'The origin of the proteid vacuoles is not at all clear although there is no doubt about their being a kind of nutritive substance.' In regard to the migration of the whole nuclei from the jacket cells into the archegonium described first by Arnoldi (2), the present writer's observations are in accord with those of Ferguson (24), Murril (51), and Miyake (46) who all failed to see such migrations.

The writer opines that the proteid vacuoles are formed from ordinary vacuoles which are quite numerous in the egg. These vacuoles get filled up with a substance which is secreted by the egg cytoplasm and ultimately form what have been termed proteid vacuoles. Plate III fig. 17 shows vacuoles in the course of being filled up. It is believed that these proteid vacuoles serve a nutritive function. The writer had written out this part of the text when he saw a recent paper by Chamberlain (11) on the 'comparative morphology of cytoplasm and chromatin.' Chamberlain describes that ordinary vacuoles in the eggs of cycads get filled up with globules which stain deeply with safranin and iron-alum-haematoxylin. Obviously he is referring to the proteid vacuoles.

It may be noted in passing that all the archegonia in a prothallus at a certain time are at the same stage of development till the maturation of the egg. If in one the central cell is dividing to cut off the ventral canal cell, the others in the same prothallus would, it is highly probable, show a karyokinetic figure at the same stage.

The Receptive Spot.

When the egg nucleus has become mature, a large circular cavity appears in the egg cytoplasm just below the neck (plate III fig. 18).

Sometimes its outline indicates that it has been formed by the coalescence of two or more such cavities. The writer agrees with Ferguson (23, 24) in regarding this cavity as the 'receptive spot.' Other authors, for example Blackman (3), regard this cavity to have been formed by the sudden in-rush of the contents of the pollen-tube, but since it has been seen by the writer before the pollen-tube has discharged its contents into the archegonium, it is not formed as supposed by Blackman. It is very likely that this cavity or vacuole serves to keep a clear passage ready for the contents of the pollen-tube to enter the cytoplasm of the archegonium. This is further borne out by the fact that this vacuole becomes filled up with the cytoplasm discharged by the pollen-tube into the archegonium.

Contents of the Pollen-Tube.

The progress of the pollen-tube and the divisions of the nuclei in it have not been worked out by the writer in *P. longifolia*. When the pollen-tube is just above the archegonium (i.e., between the female prothallus and the nucellus) it contains the stalk cell, the tube nucleus and the two male nuclei enveloped in a common sheath of cytoplasm. Plate V fig. 19 shows the end of the pollen-tube just between the female prothallus and the nucellus containing the two male nuclei in the common sheath of cytoplasm. The male nuclei appear to be in advance of the other two at this stage. The stalk cell and the tube nucleus were seen in the other succeeding sections at about the same place. When the pollen-tube passes through the archegonial chamber of the egg and reaches the neck, the neck cells are in many cases crushed but in some cases they retain their identity. Then the pollen-tube opens by a definite pit and discharges all its contents into the egg. Some starch grains and some cytoplasm are also passed in. (The writer has not tried the iodine test on these particular grains but since the pollen-tube and the surrounding nucellar cells contain starch grains at a slightly earlier stage, it is highly probable that these grains which are passed in are also of starch). Generally the cytoplasm of the egg and that from the pollen-tube cannot be distinguished from each other but in some cases the cytoplasm from the pollen-tube is very large in quantity and takes a different shade of the stain from that which the cytoplasm of the archegonium takes. Plate III fig. 20 shows quite a large quantity of the cytoplasm which has been passed into the egg from the pollen-tube.

Fecundation

On entering the archegonium the two male nuclei free themselves from the enveloping sheath of cytoplasm. They differ slightly in size and it is the large one which is seen moving towards the female

nucleus just as Ferguson (24) found in the species of pines on which she worked (plate V fig. 21). Ferguson says that there is no bulging of the egg nucleus towards the male nucleus when the latter approaches the former, but in one of the writer's preparations (plate V fig. 22 and plate III fig. 23) the male nucleus is seen approaching the female nucleus and the latter has produced a distinct bulge towards the former. Corresponding to the bulge on one side of the female nucleus, there has been produced a concavity on the opposite side. But how far this is normal the writer is not prepared to vouchsafe. Blackman (3) in comparing the sizes of the larger male nucleus and the female nucleus states, 'The ratio of the diameter of the male nucleus (which has a nearly spherical form) to the long axis of the (ellipsoidal or egg-shaped) female nucleus at the time of the fusion is usually about one-third, but cases have been observed in which it is as much as one-half.' The present writer has not come across any cases in which this ratio approaches one-half. In all the cases which came under his observation the ratio was about one-third.

On reaching the female nucleus the male nucleus becomes lodged in a depression on the upper side of the former (plate V fig. 24). This is figured from a preparation fixed near Chamba on 1st July, 1920.

The next stage which the writer was able to secure corresponds exactly to Blackman's (3) fig. 23, plate 13. It shows the former limits of the female nucleus within which towards the upper side the first segmentation spindle is formed (plate III fig. 25). The spindle is wholly intra-nuclear and the paternal chromosomes cannot be distinguished from the maternal. A number of thin rod-like chromosomes can be seen. This stage was fixed at Lahore on 30th April, 1921. Now Chamba is 125 miles, as the crow flies, to the north-east of Lahore. The latitude of Lahore is $31^{\circ} 30' N$; the longitude is $74^{\circ} 15' E$; and the altitude 720 feet above sea-level. The latitude, longitude, and altitude of Chamba are $32^{\circ} 29' N$, $76^{\circ} 10' E$, and 3,027 feet above sea level respectively. For this distance and altitude the development near Chamba is late by two months.

The two nuclei formed as a result of the first division are seen in (plate V fig. 26). These nuclei divide simultaneously and very soon. Plate III fig. 27 represents one of them. The directions of these mitotic figures bear no definite relation to the direction of the preceding mitotic figure. The spindle is not surrounded by a clear space crossed by bands of protoplasm as figured by Blackman (3) for *P. silvestris*.

Fate of the other nuclei from the pollen-tube.

The second male nucleus, and the stalk cell are disorganized very quickly. In some cases by the time the fertilized nucleus has divided

into four segmentation nuclei they cannot be traced at all. The writer has seen one of these nuclei dividing mitotically just beneath the neck of the archegonium as described by Ferguson (23, 24), but it is extremely hazardous to state which it was. The tube nucleus which is fairly large (or which is the largest of all the nuclei in the pollen-tube) has been seen by the writer lying immediately below the neck-cells of the archegonium in many cases and so blocking the passage. It is often quite spherical and contains some dark staining granules. In other cases it is somewhat compressed and shows a distinct reticulum. The writer thinks that the former case shows only a disorganizing tube nucleus at a later stage than that at which it shows a distinct reticulum. When it is disorganized completely a very thick wall-like structure is to be seen below the neck which the writer takes to represent the last remains of the disorganized tube nucleus.

The Four Segmentation Nuclei.

The four segmentation nuclei when they lie about the centre of the archegonium are generally elongated in form. They are surrounded by fibres which lie very close to the nuclear membrane. These fibres become more pronounced during the descent of the nuclei towards the base of the archegonium (plate IV fig. 28). When the nuclei have reached the base of the archegonium they arrange themselves in one plane. No nucleoli are to be distinguished in these nuclei at any time. Plate IV fig. 29 shows the nuclei arranged at the base of the archegonium. They show an open reticulum at this stage and the staining material is rather small in comparison to the size of the nuclei. The cytoplasm about the nuclei shows a fine granular structure but the granules are slightly bigger than those of the cytoplasm in the upper part of the archegonium. Moreover this cytoplasm surrounding the four nuclei stains differently from the general cytoplasm of the archegonium. It takes the gentian violet readily. At this time the fibres surrounding the nuclei seem to have disappeared.

Pro-embryo and wall-formation.

The divisions of all the four nuclei take place simultaneously. The spindles show a range of variation, the poles being sometimes normal and sometimes truncated. A very obvious change has taken place in the cytoplasm surrounding the dividing nuclei. It shows very big coarse granules but there is an area of clear space with fine granules immediately surrounding each spindle. Only one of these spindles is seen in plate IV fig. 30, although as above remarked all the nuclei divide simultaneously.

The cross-walls in the pro-embryo are formed in connection with the first division of the four nuclei. Vertical wall-formation in the pro-embryo also begins at this stage. Kildahl (34) thinks that the vertical walls are formed in connection with secondary fibres which radiate from the spindle in the first division but since the present writer has not been able to see any radiating fibres, he thinks the fibres which go to form the vertical walls, arise independently in the cytoplasm. The formation of these vertical walls begins in the middle and proceeds both ways, towards the base and the top.

This wall-formation in *P. longifolia* does not fall in a line with the observations of Blackman (3) on *P. silvestris*. This writer reports wall-formation at the 4 nuclear stage. Ferguson, (24) however, disagrees with Blackman and states that 'in the five species of pines which I have studied cell-walls do not arise until after 8 nuclei have been formed.' This is exactly what obtains in *P. longifolia*.

Most of the coarse granules in the cytoplasm referred to above disappear when the pro-embryo shows four lower cells (completely walled) and four upper nuclei (because they are open above plate IV fig. 31).

The next division in the pro-embryo takes place in all the nuclei of the upper tier simultaneously (plate IV fig. 32). Kildahl (34) states that it may take place in the lower tier also, but this has not been observed by the present writer. Miyake (46) found in *Picea excelsa* that the cells of the upper tier divide first as found in *P. longifolia*. Cross and vertical walls are formed as before. The pro-embryo thus reaches the three tiered stage (plate IV fig. 33) with four cells in each tier. The uppermost nucleus is not seen in the section sketched. The cells of the middle tier seem as if wedged in between the other two tiers.

The next and the last division in the pro-embryo takes place in all the cells of the lowermost tier simultaneously. This again is as it happens in *Picea excelsa* as reported by Miyake (46). Thus the pro-embryo reaches the four-tiered stage. The pro-embryo has now completed its development and consists of three tiers of four cells each, which are completely walled, and the uppermost tier of four cells which communicate with the cytoplasm of the egg on the upper side.

Formation of the Embryo and the Suspensor.

After the pro-embryo has completed its development the cells of the second tier (suspensor tier) from below or the third tier from above, begin to elongate (plate IV fig. 34). A very long suspensor is thereby produced which carries the lowermost tier of four cells (the embryo tier) down into the female prothallus. As the growth of the embryo proceeds the cells of the axial region of the female prothallus

NAME OF SPECIES.	Locality with Latitude and Longitude etc.	Initiation of Female Cone.	Megaspore-mother-cell	Reduction divisions in the mother-cell.	Second Winter Condition of female Proth.	Cutting off of the Ventral canal cell.	Syngamy	Pollination	Author
<i>P. Laricio.</i>	Chicago : Lat. 47° 50' Long. 87° 37'	Late fall and winter Oct.?	May	...	Parietal layer of free nuclei	21st June	1st July	Mid. June	Chamberlain (7, 10, 14)
<i>P. maritima.</i>	Various Localities	Early March	...	...	32 or more nuclei	...	...	1st Oct.	Ferguson (24)
<i>P. rigida.</i>	Various Localities	Early March	15th May	5th June	32 or more nuclei	...	...	27th May	Ferguson (24)
<i>P. Strobilus.</i>	Various Localities	Last week of April and May	20th June (about)	1st division 27th June	32 or more nuclei	...	21st June	Late May or early June	Ferguson (24)
<i>P. austriaca.</i>	Various Localities	...	...	6th June 1st division	32 or more nuclei	...	...	...	Ferguson (24)
<i>P. silvestris.</i>	...	Jan.-Feb.	...	...	...	...	...	End of May	Strasburger
<i>P. longifolia.</i>	Lahore : Lat. 31° 30' Long. 74° 15' Alt. 720 ft.	January	Mid.-Feb.	End of Feb. or early March	A few parietal nuclei	29th April, 1921	30th April	Mid. Feb. 2nd and 3rd week	M. L. Sethi
<i>P. longifolia.</i>	Chamba : Lat. 32° 29' Long. 76° 10' Alt. 3,027 ft.	...	...	...	...	21st April, 1922	1st July	...	M. L. Sethi

TABLE I.

assume an elongated form, parallel to the long axis of the prothallus. Thus they seem to offer less resistance to the downward pushing of the embryo. These prothallial cells and others at a fair distance from the embryo are rich in granular contents which have been tested for starch and give the characteristic blue reaction with iodine solution. This starch seems to be for the nourishment of the growing embryo.

Discussion.

It has been stated that the proximal parts of the basal whorls of scales protecting a cluster of male cones stick on to the branches for thirteen years in some cases. Such branches are almost equal in thickness near their apical and basal ends. Apparently, therefore, it seems that very little secondary growth takes place, if at all, during these years. It has been observed that however young an axis may be (even two or three years) if it happens to branch, secondary growth in the parent axis is very vigorous. As a result it grows in thickness very soon. If no branching takes place a shoot may remain without appreciable secondary growth for a long time.

In regard to the female cone and the megaspore-mother-cell the writer's observations are generally in a line with those of Ferguson (24) on *Pinus* species. The case of *Pinus Laricio* (14) in the vicinity of Chicago is rather interesting. In this species the female cone begins to develop at about the same time as in *P. longifolia* but development continues till October when the resting period begins. The resting period begins just in the beginning of winter. In *Pinus longifolia* the resting period begins in May which marks the beginning of summer in Lahore and continues through the succeeding winter. So while the cones in *P. Laricio* continue to grow through summer, those of *P. longifolia* stop their growth just in the beginning of summer. Table I has been compiled for the sake of comparison from the data available for different species of *Pinus*. It is obvious that the schedule for *P. Laricio* given by Coulter and Chamberlain (14) is applicable to *P. longifolia* in Lahore with slight modifications. Syngamy takes place in Chamba about the 1st July. This date is identical for *P. Laricio* in Chicago. It seems, although actual observations have not been made (except the one given above), that the schedule for *P. longifolia* in Chamba may be identical with *P. Laricio* in Chicago.

The megaspore-mother-cell in *P. longifolia* becomes evident very early in the life of the ovule. It is one of the deep-lying cells of the nucellus. The only reference which is not in accordance with this general rule is that for *Larix* (66). In this case Strasburger found an hypodermal archesporial cell, which divided periclinally into an outer primary wall cell ('tapetal cell') and an inner primary sporogenous cell.

In having a single megaspore-mother-cell *P. longifolia* is similar to the other species of *Pinus* so far investigated and *Larix*. This number is constant in the Abietineae but is not so in Taxodineae and Cupressineae. Another feature which distinguishes the Abietineae from the Taxodineae is the presence of the spongy tissue about the megaspore-mother-cell in the former.

As in the other Abietineae this deep-seated megaspore-mother-cell undergoes meiosis. The female gametophyte develops in the same manner as in the other Coniferales and also in Cycadales and Ginkgoales. The archegonial initials can be located as soon as the gametophyte shows a continuous tissue. They follow the same course of development as those of other Pinaceae. The venter of the archegonium shows a very vacuolate cytoplasm. When the archegonium nears maturity these vacuoles become filled with a certain substance and form proteid vacuoles. This is exactly similar to what has recently been described by Chamberlain (11) for Cycads. These proteid vacuoles were at one time supposed to be the nuclei of the surrounding jacket cells which had migrated into the archegonium. 'Even after Strasburger had shown that these deeply staining masses are not nuclear in nature, but the best organized are the so called proteid "vacuoles," Arnoldi (2) described the behaviour of migrating nuclei' (14). Coulter and Chamberlain (14) have argued that 'the bodily transfer of nuclei or any solid material is impossible.' Now Chamberlain for Cycads and the present writer for *Pinus* have actually seen them arising within the egg cytoplasm, so that if final and definite proof against the migration of nuclei was needed, it has been given for two Gymnosperms.

A 'notable feature of the Abietineae is the formation of a true ventral canal cell.' Among the Taxodineae the ventral canal nucleus is cut off but no cell-plate is laid down. This nucleus is sometimes very ephemeral. In the Cupressineae the ventral nucleus is cut off but it is very evanescent, perhaps more so than in the Taxodineae. Among the Araucarineae in *Agathis* a ventral canal nucleus is cut off (Ghose 29) but it is not mentioned whether it is as ephemeral as in the Taxodineae and Cupressineae. In *Araucaria* Burlingame (5) states 'the central cell of the archegonium divides very late or perhaps not at all, except in cases of delayed fertilization.' So *Araucaria* most nearly approaches, in this respect, *Torreya* (15) in which there is no ventral canal cell, the nucleus of the central cell becoming the egg nucleus.' From these observations the general tendency among the Coniferales towards the elimination of the ventral canal cell is quite obvious.

In regard to the period that elapses between pollination and syngamy recorded cases according to Coulter and Chamberlain (14

fall into two categories. One of them includes cases in which pollination occurs in one season and syngamy the next. The other in which pollination and syngamy occur during the same season. *Pinus longifolia* belongs to the first category. Table I gives the relative dates for different species of *Pinus* in different localities.

The female nucleus does not get surrounded by a cytoplasmic mantle as is known for *Torreya taxifolia* (15), *Juniperus* (52, 53) *Taxodium* (13), *Sequoia* (37), *Thuja* and *Ephedra* (36). From what has been stated above about syngamy, it is clear that *P. longifolia* agrees with other species of *Pinus*. A close series of stages being not available to the writer, he is not in a position to say whether cross-segmentation of haploid number of chromosomes after pairing does take place in *P. longifolia* or not as has been described in *Abies* by Hutchinson (33).

In *P. longifolia* and in all the species of *Pinus* on which Ferguson (24) worked, she found that cell-walls do not arise in the pro-embryo till after eight nuclei have been formed. In *P. silvestris* it is stated by Blackman (3) that wall-formation takes place at the four nuclear stage. So within the limits of a single genus in which the various species show so close a resemblance in other respects, the wall formation in the proembryo may not be similar. In the genus *Picea* (46) wall-formation takes place exactly as in the majority of *Pinus* species. Then in regard to the mode of origin of these walls there seems to be some disagreement. Kildahl (34) states that the vertical walls are formed in connection with secondary fibres which radiate from the spindle in the first division. Ferguson (24) does not say anything on this point. The present writer thinks that these walls arise quite independently of the spindle fibres because he was unable to see any radiating fibres. This mode of wall-formation in the pro-embryo of *Pinus* finds an analogy, though very remote, to the condition met with in *Stangeria* (9). From the figures which Chamberlain (9) gives for this genus, it seems that walls in the pro-embryo are not laid down in connection with any spindle fibres but arise independently in the cytoplasm.

V. Microsporogenesis.

Introductory.

In the years 1920, 1924 and 1925 male cones of *Pinus longifolia* were sectioned by the writer by the paraffin method. Flemming's weak and strong, Herman's, Bensley's and corrosive sublimate (aqueous) solutions were tried as fixatives. It was found that excepting the earlier stages of development the paraffin method after any of the above fixatives was not successful. By this method good preparations were secured up till the formation of the microspore-mother-cells. But as soon as the mother-cells entered upon the first

heterotypic division the fixatives failed to fix properly. This seems to be due to the inability of the fixatives employed to enter the cells. And the cause of this impermeability of the cells, the writer opines, is the large quantity of a resinous substance in the sporophylls and the axis of the male cone.

Lawson (37) in his paper on *Sequoia sempervirens* makes the following statement:—"There are few groups of plants that offer more difficulties in the way of cytological research than the Coniferales. The structures that are of greatest cytological interest are usually buried deep in the other tissues thus requiring very careful dissection before being placed in the killing fluids. Then, again, if resin is present, as is usually the case, a rapid penetration of the fluid is impossible." Burlingame (4) working on *Araucaria brasiliensis* mentions some similar difficulties and because of these he could not follow the reduction divisions closely. He figures only a few stages.

Chamberlain (10) recommends a method for following spermatogenesis in *Pinus*. That method was tried but could not be followed because the divisions in the microspore-mother-cells of all the sporangia in a cluster of male cones are almost simultaneous. It was always found that the same stage of development obtained in the apical male cones of a cluster as the one found in the basal male cones. So that material had to be fixed in the field day after day.

In the winter of 1925-26 Flemming's weak fluid was again tried. The material after being fixed and washed was dehydrated very carefully beginning with 5% alcohol and brought up through 10%, 20% etc. It was found that even with all these precautions the mother-cells were plasmolysed. In January 1926 Taylor's (72) smear method was tried for the reduction divisions. Taylor in describing his method recommends slides cleaned by a long stay in battery fluid to ensure fixation of the mother-cells. The present writer used ordinary new slides and felt no difficulty whatever. Before making a smear stamens from a cone were always crushed in water and examined in the field to see if they were at the right stage. After this preliminary survey, a cone from the vicinity of the one which showed any desirable stage was taken and cut longitudinally into two halves. One of these two halves was always discarded and the other rubbed smartly with the cut surface downwards on a clean slide to obtain a smear. Examination of the slides after staining showed that by far the best preparations were those in which the cut cone was dragged but once on the slide. Obviously this gave a thin smear and took less time than otherwise. Moreover a second rub would mechanically tend to remove the material which might adhere to a slide after the first rub. The smear being made the slide was then placed with the smeared face downwards on a glass rod in a petri-dish containing

the fixative according to Taylor (72). In doing this great care had to be exercised to bring the entire smear into contact with the fixative all at once. The slide was allowed to remain in this condition for two or three minutes and then turned right side up. The fixative was allowed to act for 15 minutes in all. The slide was then transferred to a tube containing water. A number of slides prepared in this way after one or two changes of water were carried to the laboratory while still in water. Washing in water was done usually for about an hour or so. After bleaching with hydrogen peroxide solution the slides were stained as usual. Heidenhain's iron-alum-haematoxylin was used for staining throughout. No difficulty was met with in obtaining brilliantly stained preparations.

By the above method very good slides were secured and the reduction divisions followed in a very short time indeed. The smear method proved successful where the ordinary paraffin method had failed.

Taylor (72) has employed this method mainly for Monocotyledonous plants. The experience of the writer shows that it can be used for Gymnosperms as well.

The fixative used in 1926 did excellently for the nucleus. When living material was again examined in 1927 it was found that the fixation of cytoplasm was not so perfect. Therefore to fix the cytoplasm more satisfactorily Gatenby's (26) suggestion of leaving out acetic acid from the fixative was followed. Flemming's strong without acetic, Taylor's without acetic, vapours of osmic followed by Regaud's were used simultaneously with Taylor's to compare and contrast the effects on cytoplasm. The fixation of cytoplasm was no better with the first two fixatives than heretofore while Regaud's proved a failure.

Sequence of Development in the Male Cones.

The clusters of male cones are initiated in the month of September in the vicinity of Lahore, Lat. $31^{\circ} 30' N.$, Long. $74^{\circ} 15' E.$ and Altitude 720 feet above sea-level. Material fixed on the 26th September, 1920 showed the individual male cones as conical axillary structures consisting exclusively of meristematic cells. During early October the individual microsporophylls become distinguishable. On the 18th October, 1920 the fertile proximal part of the microsporophyll was observed marked off from the sterile distal part. In cones fixed on the 26th October, 1920 the two microsporangia were seen delimited from each other in as much as there were two or three layers of vegetative cells between two patches of meristematic cells on the two sides. It should not be understood that all the cones in a cluster are at the same stage of development. While those near the base

approximately show the stages for which the dates have been given above, those near the apex are usually much younger at this time.

Gradually by the 11th November the 3 or 4 wall layers of the sporangium get defined. By the 15th December the cells of the outermost layer of the wall get filled up with resin. Such cells in sections appear filled up with a homogeneous substance. Ferguson (24) states that such cells lose their nuclei. The writer has observed nuclei in these cells in cones fixed as late as January 24th. By this time most of the cells of the sporophyll and the cells of the wall except the two innermost layers get this resiniferous deposit (plate VI fig. 35). It is this deposit, the writer thinks, which hinders the penetration of the fixatives by the ordinary paraffin method.

Demarcation of Dehiscence.

The cells of a longitudinal plate of 3 or 4 cells towards the mid-ventral line of the sporangium do not get filled with the resiniferous substance (plate VI fig. 35). This is about the third week of January before the reduction divisions. It is in the middle line of this plate of cells that dehiscence takes place later on when the spores are ripe. So far as the writer is aware no one has made a mention of this demarcation of dehiscence or figured this plate of cells in *Pinus*. In the microsporangium of *Ceratozamia*, however, Chamberlain (8) has described and figured a similar structure.

The tapetum as a distinct layer was made out in cones fixed on the 15th December, 1924. It appears to be the modified outermost sporogenous layer because some cells more like the sporogenous cells lie in between the tapetal cells. Ferguson (24) states that in the species of *Pinus* which she studied except *P. Strobus*, the tapetum cannot be distinguished during the early stages of development from the other tissues. It is first clearly differentiated in spring when the mother-cells are in the early prophase of the heterotypic division. The present writer's observations go to show that the tapetum as a distinct layer is differentiated in *P. longifolia* much earlier in the life-history when compared with *P. rigida*, *maritima*, etc.

The growth and divisions of the sporogenous cells since the earliest stages, are continuous and uninterrupted till the pollen-mother-cells become recognizable in January. In *Pinus longifolia* there is no winter rest either before or after the formation of the mother-cells or pollen grains. The mother-cell stage in *P. longifolia* is reached in January after continued growth and division. Before the reduction divisions the scales in the axils of which the male cones arise are closely appressed to the cones themselves. When the mother-cells have been fully formed and are ready to enter upon the heterotypic division, the scales open out. This is apparently due to

the growth of the male cones which takes place vigorously at this time. So the position of the scales can serve as an index for the reduction divisions. In the year 1925 the reduction divisions in the pollen-mother-cells were observed from the 23rd January to the 1st of February. In 1926 these divisions were observed from the 24th of January to the 1st of February. This overlapping of dates was a very fortunate coincidence. It should not be supposed that reduction divisions take place during the same days every year. There may be a slight shifting backwards or forwards of this time in different years. This shifting has been attributed to climatic factors by Chamberlain (10).

During the first week of February the male cones elongate rapidly, the sporangia open along the middle line of the plate of cells already indicated and the pollen grains are shed.

The Reduction Divisions in the Pollen-Mother-Cells.

The mother-cells before entering upon the heterotypic division.—The reduction divisions as stated above take place in *P. longifolia* during the last week of January. The mother-cells immediately before this are very closely packed within the sporangium. Only the tapetal cells are loose and seem to be undergoing disorganization. The mother-cells themselves are polygonal (plate VI fig. 36). The cell walls are thin. The nucleus is very large when compared with the size of the cell and the quantity of cytoplasm contained. The nucleus seems to fill the entire cell cavity, the cytoplasm being confined to the corners only (plate VI fig. 37). In form the nucleus is approximately spherical. It shows a close linin network with small chromatin granules uniformly distributed upon it. The chromatin granules are not confined to the net-knots of the linin threads only. They are found along the threads too, although the size of those granules found at the net-knots may be appreciably larger than those of the rest. The number of nucleoli has been counted in sections and may be 3 or 4 in any one of them. It is very difficult to count their actual number in a nucleus. Their staining reaction is very faint and some of them are vacuolate.

The structure of the nucleus at this time in *P. longifolia* is similar to that described by Lewis (42) for *Pinus Strobus*. The writer can fully support the view expressed by Lewis for *P. Strobus* and Woolery (76) for *Smilacina* that the number of chromatic bodies in the resting nucleus bears no definite relation to the number of somatic chromosomes as has been shown for a number of plants; viz. in *Thalictrum purpurascens*, *Helleborus foetidus*, and *Campanula grandis* by Overton (55) and in *Carex* by Stout (71).

The cytoplasm of the mother-cell is vacuolate. There are mitochondria or chondriosomes both of the filamentous and the spherular type. These latter structures the writer interprets as such because Mottier (50) working by a similar method found chondriosomes in *P. banksiana*. The spherular type of mitochondria were visible in the material in the living condition when examined in the field in water. At that time they looked like blue green homogenous bodies.

Prophase.—During early prophase the staining reaction of the chromatin granules increases remarkably (plate VI fig. 38). The granules increase in size also till they look like droplets. Their size and number is so large that the original linin threads get obscured. This proceeds on gradually till the reticulum retracts from the nuclear membrane (plate VI fig. 39), and forms a close knot (the synizesis stage) along one side and the major part of the nuclear cavity remains empty (plate VI fig. 40). In many mother-cells it was found that the synizetic knot remains connected with the nuclear membrane by strands as shown by Mottier (49), and Woolery (76). No membrane, however, could be indentified around this synizetic knot as reported by Latter (41) for *Lathyrus*.

Near the close of synizesis stage a continuous thin spireme can be made out within the synizetic knot (plate VI fig. 41). This continuous chromatic thread shows alternating heavier and lighter parts along its length.

These prophasic changes may not be simultaneous in all the mother-cells. While some may be showing early synizesis others may represent close of synizesis. In the cytoplasm the spherular type of mitochondria become more prominent.

The writer could not make out in the pollen mother-cells of *P. longifolia* anything like the fibres which have been figured by Allen (1) in the pollen mother-cells of *Larix* during prophase. Neither has Lewis (42) seen anything similar to them in *Pinus* and *Thuja*.

The chromatic thread seen during the close of the synizesis soon uncoils itself and becomes uniformly distributed within the nuclear membrane but more or less peripherally (plate VI fig. 42). Only one or two nucleoli can be made out within the nucleus at this time, the others seem to have disappeared. The staining reaction of the nucleus as a whole seems to decrease. This may simply be due to the spreading out of the spireme and thus may be only apparent and not real. The spireme is so long that after complete recovery there are so many turns and twists in it that one cannot trace its course within the nucleus. This is the open spireme stage.

It is during this recovery after the first contraction that the mother-cells round off and glide on one another and so become loose.

Lewis (42) reports the loosening of the microspore-mother-cells in *P. Strobus* at exactly the same stage.

After the cells have become loose the spireme shows longitudinal splitting at certain places (plate VII fig. 43).

The spireme gradually shortens and its thickness gradually increases and the split disappears. This is the pachynema stage. Soon after this a second contraction takes place (plate VII fig. 44). As this figure shows this contraction does not result in the formation of such a compact knot as the first contraction. In some cases a more well pronounced second contraction was seen (plate VII fig. 45) but the writer is not sure whether it is well marked in all cases. Fig. 45 shows some very fine achromatic strands radiating from the nuclear knot at this time and reaching the nuclear membrane. By means of these the nuclear knot seems to remain anchored within the latter. Lewis (42) and Ferguson (24) make no mention of this second contraction. When these writers published their accounts the first contraction even was held in doubt. It was believed to be an artifact. Cardiff (6) wrote in 1906 as follows:— 'In fact, the knot seems to be as often, if not more often, on the side of the cell where there is least cytoplasm. It was generally found, however, that in any one sporangium or group of sporangia all the knots occupy the same relative position in the nuclei. I offer as a tentative explanation of this, that the chromatin mass is of greater density than the nuclear sap and the position of the nucleolus and knot is due to gravity.' Keeping this in mind the second contraction which is not so pronounced might have been overlooked by these writers, but since that time the first contraction has been recognized as a normal phase in the heterotypic division.

When the chromatic thread recovers from this second contraction it is very much thicker than during any of the earlier stages and shows a number of loops (plate VII fig. 46). No nucleoli could be made out in the nucleus at this time. These loops have been reported for *Lathyrus* by Latter (41) and by Gates and Rees (28) for *Lactuca*. But in these plants the number of loops corresponds to the number of haploid chromosomes. The writer could not decide this point for certain in *P. longifolia*. Plate VII fig. 46 represents a cell where recovery has progressed to a certain stage, while plate VII figs. 47 and 48, where it is complete. The chromatic thread shows a number of large chromomeres. This thread undergoes segmentation and each loop represents a bivalent pair. It can be deduced from the behaviour of the chromatic thread that the univalents came together first of all end to end and then curved over. This shows that the chromosomes in *P. longifolia* conjugate telosynaptically as reported by Lewis (42) for *Pinus* and *Thuja*. Thus the sequence of events corresponds to

Scheme B of Sharp (63). In figures 47, 48, young bivalent chromosomes are more or less clear. At this time their outline is not quite smooth. Each pair shows a number of very large chromomeres. Later on in several bivalents the univalents get twisted about each other. Plate VII fig. 49 represents one such bivalent. So this is the strepsinema stage. The bivalent chromosomes go on condensing and thickening till the diakinesis stage is reached (plate VII fig. 50 and plate X fig. 51). At this stage the bivalents exhibit fairly smooth outlines. They are found very much scattered within the nucleus.

At the diakinesis stage, (plate VII fig. 52 and plate X fig. 53), each univalent chromosome of a bivalent pair, in some cases, shows a longitudinal split. The writer is not sure whether this is the reappearance of the same split which is seen during earlier prophase. This results in the formation of chromosome tetrads. In many cases the chromosomes remain adherent at one end but lie widely apart at the other end. Some of these bivalent chromosomes may remain in telosynaptic union till this stage. Such telosynaptic bivalents have been described during late diakinesis for *Oenothera* (Gates 27) and *Carex* (Stout 71).

No worker, so far as the writer is aware, has reported chromosome tetrads in any species of *Pinus*. They have been reported however in a large number of animals and some plants.

Metaphase.—At the close of the diakinesis the nuclear membrane disappears and the spindle fibres make their appearance. The spindle fibres converge to very fine points at the spindle poles. During metaphase the chromosomes are very thick, stumpy and deep staining. In these metaphasic chromosomes the longitudinal splits which had resulted in chromosome tetrads during prophase become invisible. These splits become visible again during the close of metaphase (plate VIII fig. 54). The chromosomes in this figure are just going to part company. At this point the writer finds evidence to support Lewis (42) rather than Ferguson (24). The former states that the bivalents separate into constituent univalents, while the latter supposes that the chromosomes separate along the longitudinal splits and so half of each somatic chromosome passes to each daughter nucleus and thus this mitosis according to Ferguson (24) effects an equational division.

In figure 54 the split univalent chromosomes are like Vs, the angle of the V being directed towards the pole. The univalent members of a bivalent pair are very much alike in size and shape, *i.e.*, they would coincide exactly if placed one over the other. Bundles of spindle fibres can be seen attached to the apices of Vs.

Anaphase.—As soon as the anaphase begins the distance between the arms of Vs decreases and chromosomes look like Us. Plate VIII fig. 55 represents a cell in which anaphase has progressed pretty far. The chromosomes are pretty long (*i.e.* they are longer than during metaphase or prophase). It may be concluded that they get elongated during anaphase due to a pulling strain being exerted on them by the spindle fibres. However, all are not of the same length. In the two groups of chromosomes, the longer and shorter all show their former mates of corresponding size and shape. From plate VIII fig. 55 one can infer that the separation of the univalents in all the bivalents took place almost simultaneously. The split halves of chromosomes have a tendency to approximate still more closely and may ultimately come to lie almost parallel to each other. These observations are almost identical with those made in *Pinus Strobus* and *Thuja* by Lewis (42).

In each of the two batches of chromosomes four very long chromosomes can always be detected. They show constrictions near their ends which are towards the equator of the achromatic figure.

Telophase.—The chromosomes having migrated to the poles the spindle fibres become very prominent in the region of the equator (plate VIII fig. 56), and can be fairly well made out in living material in the field. There is considerable overlapping of the fibres in the equatorial region. After reaching the poles the outlines of chromosomes remain distinct for a time and the splits are also visible in many of them.

The chromosomes of each daughter nucleus contract into a very compact mass which shows very few light areas. The outlines of individual chromosomes are obviously lost (plate VIII fig. 57). The chromosomes again separate and organize themselves into a network by branching. The branches may be attenuated. The branches fuse and ultimately typical resting nuclei are developed (plate VIII figure 58). This behaviour of telophasic chromosomes corresponds to mode 1. of Litardière (43). There is no thickening of spindle fibres or deposition of granules in the equatorial region of the spindle but in a few cases a very fragile cell-plate has been seen.

No nucleoli appear in the daughter nuclei during interkinesis. Ferguson (24) makes a similar statement.

Cytokinesis.—Karyokinesis is not followed by cytokinesis as is generally the rule. The cell-plate is not to be seen during late telophase. It is concluded that it disappears very soon (plate X fig. 59.)

A constriction furrow develops between the two daughter cells during interkinesis. It is fairly well marked but does not make much progress till after the second homotypic division. Harper (31) found in

Larix that no cell-plate followed the first division of the pollen-mother-nucleus and that the spindle fibres of the primary mitosis were utilized in the formation of the spindle fibres for the second division.

Ferguson (24) on this point states, "Contrary to the observations of Hofmeister (32) no cell wall is laid down and in only a very few instances has a slight thickening of the spindle fibres in the region of the cell-plate been observed." She found no spindle fibres of the first division persisting till the second division as Harper did. The writer does not agree with Ferguson. And neither does she say anything nor does she figure the invagination.

Second homotypic division.—The second homotypic divisions are initiated simultaneously in the two daughter cells formed after the first heterotypic division. The relative position of the two mitotic figures is very variable.

Prophase.—The earliest prophase is denoted by the reticulum of the nucleus becoming more open (plate VIII fig. 60). This is followed by an increase in size of the chromatin granules and their reaction to stains. Some of them coalesce into one another. This proceeds in such a way that a more or less continuous spireme is formed. This spireme in the beginning is not of uniform thickness but looks jagged. Gradually the chromatic material becomes evenly distributed along the length of this spireme. It undergoes a certain amount of shortening accompanied by consequent thickening. Ultimately it segments into a number of chromosomes (plate VIII fig. 61). They are fairly and uniformly thick. The chromosomes lie entangled among themselves. The entire mass of chromosomes fills about $\frac{2}{3}$ of each cell (plate IX fig. 62).

Here again, in the behaviour of the spireme the writer finds evidence to support Lewis (42) rather than Ferguson (24). The latter states that the spireme forms loops across the spindle and as cross-segmentation proceeds the loops undergo longitudinal fission. According to Ferguson the spireme takes its position on the equator of the spindle, while according to Lewis and the writer the spireme segments much earlier into the chromosomes. The nuclear membrane disappears and the chromosomes occupy the equator of the achromatic figure (plate IX fig. 63).

Metaphase.—The chromosomes are pretty long structures at this time but not so very thick (plate IX fig. 63). When lying at the equator of the achromatic figure their longer axes are parallel to the longer axis of the spindle. They show longitudinal splits very clearly. The equatorial plate of chromosomes is fairly broad and almost fills the whole of the cell breadth-wise. This mitotic figure presents a very sharp contrast to the same stage of the previous heterotypic division.

The spindle fibres are very weakly developed at this time or they are not brought out very clearly by the smear method. Ferguson (24) also does not figure them very prominently, so that one can infer that they are really weakly developed and that the smear method is not to blame.

The metaphase when compared with the prophase lasts for a shorter time. This, the writer deduces from the fact that in preparations where many cells show prophasic changes in progress cells showing metaphase are much fewer in number.

Anaphase.—When moving towards the poles the chromosomes become bent and so assume the form of Us or Vs (plate IX fig. 64). They lie fairly apart from one another and their angles point towards the poles. During this time the cleavage furrow which appears during the preceding interkinesis makes some progress but it is not sufficient to pinch off the two daughter cells.

Telophase.—The chromosomes after reaching the poles remain grouped together for some time with their ends pointing towards the equator (plate IX fig. 65). The outlines of individual chromosomes can be made out more or less clearly at this time. The spindle fibres which are not conspicuous either at metaphase or during anaphase become very conspicuous (plate IX fig. 65). Soon after the chromosomes contract into a spherical nucleus which develops a nuclear membrane. Within this membrane the chromosomes become united and form a skein (plate IX fig. 66). The skein seems to be peripherally placed and spirally coiled. This is quite in conformity with Ferguson's (24) observations. The skein branches. The branches run into each other. Gradually certain spots on the skein fail to take up the stain. Ultimately the resting nucleus is formed.

Since no vacuolation in the chromosomes could be made out the telophasic changes fall into group 2 of Litardière (43).

While the second homotypic division is in progress the cleavage furrow laid down during the preceding interkinesis makes some progress but does not separate the two daughter cells quickly (plate X fig. 67).

An ephemeral cell-plate can be made out during the second homotypic division. Ferguson (24) does not say anything at all in regard to this cell-plate. During the close of the first division the cytoplasm of the mother-cell separates from the wall. The furrow previously laid down proceeds afar and another invagination appears between the grand daughter nuclei (plate X fig. 67). In this way the cytoplasm of the mother-cell cleaves into four parts. While this is going on a thickening appears on the cell-wall opposite to the first furrow. This grows centripetally. Another thickening but not so large as the former

appears on the cell-wall opposite the second furrow. By the centripetal growth of these thickenings, the mother-cell which has already cleaved into four parts, becomes quadri-partitioned. The tetrads (plate IX fig. 63) may be tetrahedral or bilateral. The young spores develop their wings within the partitioned mother-cell. They ultimately come out through definite openings appearing in the outer walls of the mother-cell.

These observations on cytokinesis were confirmed in January 1927. It is advisable to remark here again that the slight amount of shrinkage which is seen in plate VIII figs. 54, 55 is not at all due to the action of the fixative because the cytoplasm of the mother-cell has been seen detached from the surrounding wall in living material examined in water. So the shrinkage is natural and cannot be attributed to the fixative or any subsequent operation.

So far as the writer is aware, among Gymnosperms, Saxton (61) only has definitely described cleaving of the microspore-mother-cells in *Tetraclinis*. He states 'the cytoplasm cleaves into four equal parts.' It is not stated whether the mother-cell becomes partitioned subsequently or not. In regard to *Juniperus* the evidence is conflicting. Norens (53) states that four spores are formed in an unpartitioned mother-cell. Nichols (52) working on the same genus maintains that the mother-cell becomes partitioned. But more of this hereafter in the discussion:

The Number of Chromosomes.—The diakinesis stage is specially well suited for counting the number of chromosomes. Accordingly at this stage several counts were made. In all clear cases 12 bivalent chromosomes were found. Among these 12, four very long ones could invariably be detected (plate VII fig. 50 and plate X fig. 51). All the rest were almost of the same length. Approximately the longer ones were to the shorter ones as 3 is to 2. So the haploid and the diploid numbers are twelve and twenty-four respectively. For counting the number of chromosomes the smear method is an advantage over the paraffin method, in as much as here one counts them in entire cells and the possibility of a mistake which is always present in counting them from sections is avoided. This is a very real advantage when one has to deal with sporogenous tissue or any other tissues in which the cells are large in size and divide simultaneously, it being very difficult to spot the same cell in two successive sections.

Starch grains in the mother-cells.—Starch grains make their appearance in the cytoplasm of the mother-cells during early prophase. They are to be seen in the cells throughout meiosis and are present in the pollen grains also. They are visible in the living material in the field and stain deeply with iodine. They cannot be seen in

preparations stained with haematoxylin after any of the above fixatives. This is the reason why they have not been shown in the figures. Their structure is homogeneous and a hilum like granule as figured by Saxton (61) in the starch grains of *Tetraclinis* cannot be seen.

The Male Gametophyte.

Two prothallial cells are cut off while the pollen grain is still within the sporangium. These cells are more evanescent perhaps than in the other species of *Pinus* because they disorganize very soon and the pollen at the time of shedding stage shows no indications of them.

Discussion.

The sequence of development of the microsporangia in *P. longifolia* is not in accord with the statements of Chamberlain (10), and Coulter and Chamberlain (14) who state that 'in most of the recorded cases the microsporangium passes the winter approximately in the mother-cell stage.'

In *P. longifolia* the writer has observed the sporogenous cells in an active state of division in December. December, 'it should be remembered, means mid-winter in the Panjab. The writer's experience is more in accord with Ferguson's (24) who seems not to agree with Coulter and Chamberlain in regard to *P. Laricio*. She states, 'Had Coulter and Chamberlain examined the microsporangia in the latter part of March they would doubtless have found typic divisions taking place in the archesporial tissue.'

In this connection it will be of interest to mention Lawson's (38) work on *Cryptomeria japonica*. In this plant male cones appear in October. Reduction divisions take place in the latter part of October or November, pollen grains are separated before the first of December and pollination takes place in the following March. Obviously in *Cryptomeria* there is no winter rest preceding the reduction divisions. In *P. longifolia* though it takes almost the same time for ripening the pollen, as has been shown above, the development proceeds in a leisurely fashion i.e. the first few stages take more time while the last few take less time when compared with *Cryptomeria*.

Robertson (58) reports, 'the male cones of *Torreya californica* pass the winter in the mother-cell condition'. The present writer has carefully gone through Robertson's paper and finds that it is difficult to reconcile this observation with what she states further on in the paper. The first collection which Robertson studied was made in November and the male cone showed 'pollen-mother-cells already formed and the cell division taking place. The nuclei are large and fill the cells'. Further, 'in cones of this

date (March 4th) a certain number of sporogenous cells are in a state of division though these are fewer than in the November material.' So if divisions in the sporogenous tissue take place in March the mother-cells are organised in spring.

Dupler (20) reports that in *Taxus canadensis* the winter at Huntingdon, Pennsylvania, is passed in the microspore stago.

So as against five plants in which there is, according to Coulter and Chamberlain, a winter rest, the writer can cite the following plants: *P. longifolia*, *P. patula*, *P. rigida*, *P. resinosa*, *P. austriaca*, *P. Strobilus*, *P. maritima*, *Cryptomeria japonica*, *Juniperus virginiana*, *Taxus canadensis*. This makes the number of genera 4 and species 10 in which there is no winter rest and if Robertson's *Torreya californica* is included the number of genera would come up to 5 and the number of species to 11. Over and above these facts, the doubts which Ferguson (24) entertains are well worth a consideration.

So winter rest is not essential for all Coniferales.

Meiosis.

From the description which has been given above it can be easily inferred that the heterotypic division follows the scheme indicated by Farmer and Moore (21) and designated as scheme B by Sharp (63, 64). Ferguson's (24) conclusions are not in a line with those of Farmer and Moore (21), Lewis (42), and other writers of that school.

It is not proposed here to discuss the differences in the views held by the telosynaptists and parasynaptists, but merely to put forward the evidence afforded by *P. longifolia* supporting telosynaptic interpretation.

Writing on Synapsis (Synizesis) in 1911 Lawson (40) interpreted the phenomenon as 'a growth period of the nucleus.' According to him synizesis consists in an 'extension of the nuclear cavity.' 'The chromatin mass is left behind and its characteristic position at one side of the nuclear membrane is a perfectly natural one.'

On this Saxton (61) writes, 'But even his (Lawson's) own figures, as mentioned in a criticism by Professor Farmer, do not support his contention.' The present writer believes that expansion of the nuclear cavity and contraction of the nuclear reticulum both proceed simultaneously, otherwise the tight synizetic knots figured for various plants and animals cannot be explained: simply by saying that the chromatic material is left behind by the growing nuclear membrane.

Sharp (64) gives a list of some plants in which chromosome tetrads have been described so far. Sakamura (59) and Chambers and Sands (12) interpret reported plant and animal tetrads as pairs of constricted chromosomes. Referring to Taylor's (73) work on *Gasteria* Sharp (64) states, 'On the other hand the newer evidence

brought forward by W. R. Taylor in his studies on the chromosomes of *Gasteria* affords strong confirmation of the suspicion that the gemini of plants really have a quadruple constitution.'

In *Pinus longifolia* the explanation of Sakamura (59) and Chambers and Sands (12) does not seem adequate. In the case of the tetrad marked A (plate VII fig. 52 and plate X fig. 53) and some others the question of constriction does not arise at all. The formation of this tetrad is clearly due to longitudinal splits appearing in the two conjugating mates. The tetrads observed in *Pinus longifolia* conform to the description of the Rod-tetrads of Wilson (75). Some are of Anaschistic type while others are of Diaschistic type.

In regard to the separation of chromosomes in the anaphase of the heterotypic division, Ferguson (24) holds that half of each somatic chromosome passes to each daughter nucleus. The writer has carefully compared Ferguson's figures with his own, and believes that there is only a difference of interpretation. If what Ferguson considers halves of two somatic chromosomes be taken for the split halves of a single univalent chromosome, as Lewis did, her observations can be brought into conformity with those of Lewis and the present writer.

Cytokinesis.

Evanescent cell-plates are laid down during the telophase of both divisions. A constriction furrow appears after the first division which makes, at any rate, a slow progress. After the second homotypic division another constriction furrow develops. These furrows cleave the mother cell into four spores. Later on due to centripetal growth of thickenings the mother-cell becomes partitioned. So the quadripartition of the mother-cell is brought about primarily by furrows and secondarily by the centripetal growth of cell-walls.

These conclusions are at variance with those of Ferguson (24) who definitely denies the presence of any cell-plate in the first heterotypic division, and makes no mention of the cell-plate in regard to the second division. She, however, did not bestow her special attention on cytokinesis.

Saxton in his paper on *Tetraclinis* (61) reviews the situation in other gymnosperms on this point. 'In Cycads investigated and *Ginkgo*, the mother-cell is chambered, the partition walls being thick and persistent.' In *Pinus* Hofmeister (32) described a cell-wall after the first heterotypic division but contrary to his observations Ferguson (24) found no cell-plate in connection with the first division. In regard to the cell-plate after the second homotypic division Ferguson does not say anything. The present writer has found evanescent cell-plates and cleavage furrows in connection with both these divisions,

After these furrows have cleaved the cell into four parts, centripetal walls divide it into four chambers. In *Larix Devisa* (17) reports that the cell-plate formed after the first division disappears and the division of the mother-cell into tetrahedral spores is brought about by cell-plates formed after the second mitosis. Burlingame (4) on this point in regard to *Araucaria* states 'no walls are formed, apparently, until after the spore nuclei have passed into the resting condition, when a system of fibres is present between the nuclei, on which the plasmatic membranes separating the young spores arise.' In *Thuja* Land's figures imply an unpartitioned mother-cell, as is also claimed for *Juniperus* by Norens (53) with whose results Nichols (52) is not in agreement. In *Torreya* (58) Robertson's figures imply an absence of chambering. In *Actinostrobus* and *Cupressus* according to Saxton (61) the spores are formed free in the mother-cell. In *Tetrachlinis* only (61) has cleaving been definitely described by Saxton.' In Gnetales *Ephedra* and *Welwitschia* (56) are not chambered, while *Gnetum africanum* and *G. scandens* (57) show thick partition walls.

Farr (22), and Gates and Rees (28) and some Swedish investigators have described a number of Angiosperms in which quadripartition by furrows takes place in the pollen mother-cells. In a recent paper McPhee (45) describes the same thing for *Cannabis*. Farr (22) makes a mention of some plants viz., *Magnolia*, *Nelumbo*, *Carex* and others in which transitory cell-plates are formed. The case of *Pinus longifolia* is very similar to *Carex* in which they are formed after both the divisions.

Although according to Saxton (61), and truly enough, this character is one which cannot on any scheme of Gymnosperm classification be of any phylogenetic importance, it still serves to bridge that gulf which at one time stretched between cytokinesis in animals and plants.

Chromosome Numbers.

Ferguson (24) has reported 12 and 24 chromosomes for five species of *Pinus* viz., *Strobus*, *rigida*, *austriaca*, *resinosa*, *montana* var *uncinata*. Chamberlain (7) reports the same numbers for *P. Laricio*. Blackman (3) and Dixon (18) for *P. silvestris* report the same numbers. Strasburger (68) has also reported 12 and 24, but his paper being not available to the writer, he cannot say on which species Strasburger worked. Thus the same haploid and diploid numbers of chromosomes have been reported for eight species of *Pinus*, including the writer's *P. longifolia* and excluding Strasburger's species.

Not only in *Pinus* but in several other Coniferales the same numbers have been reported viz :—*Larix*, *Thuja*, *Taxodium*, *Araucaria*, *Callitris* (14) and *Tetrachlinis* (61).

In this connection the following extract from 'General Cytology' (16) would be of interest:—'The most striking case of this marked uniformity of the chromosome complex is shown in extensive studies upon the short-horned grass-hoppers by McClung and his students. This family in North America consists of about 100 genera, including 800 species, and most of these have now been studied. It thus appears that throughout the group the somatic cells of the male contain twenty-three chromosomes while those of the female have twenty-four. Correspondingly, in the germ-cells the diploid numbers are twenty-three and twenty-four and the haploid eleven or twelve in the male and always twelve in the female. The significance of these figures cannot be over-estimated, for nothing but the most extreme precision of organization could preserve this common series of chromosomes through the millions of years in which this group of animals has existed, and in the innumerable multitudes of cells composing them. There is absolutely nothing to suggest the intrusion of chance into this incomprehensible picture of organic constancy.'

Sharp (63) discussing the bearing of the number of chromosomes on the origin of species and varieties states that 'the number shown by the species of a given genus or even of an entire family form a series of multiples.' 'From this it is to be inferred as suggested by McClung (44) that there is a relationship of some sort between the constitution of the chromosome complement and the externally visible taxonomic characters.' In support several cases are cited. For example, *Chrysanthemum* (species with 9, 18, 27, 36 and 45 pairs of chromosomes); *Triticum* and *Avena* (with 7, 14 and 28 pairs of chromosomes). Recently Ferguson (25) has reported seven and fourteen chromosomes for four genera of Aloinae, in each of which several species have been studied.

Now, how to explain, according to the chromosome theory of heredity, the origin of species of *Pinus* in which 8 species have been recorded to have the same chromosome numbers? There are no triploid and tetraploid or any such species. There are two ways to explain the problem. Firstly, by assuming that there is really only one species, but this would go against taxonomic conclusions which seem quite sound. The other alternative solution of the problem is that although the numbers are the same, the chromosomes are constitutionally different from one another, i.e., they differ in their factors or genes. These species might have arisen from the perpetuation of mutations which arose in the chromosomes, the number of the latter remaining constant. Change of type taking place through mutations of genes has already been emphasized by Sharp (64), Morgan (48) and others.

VI. Notes on Abnormal Female Prothalli.

In this note the writer proposes to give an account of those abnormal female prothallia he came across during his work on *P. longifolia*.

Prothallus No. 1.

This prothallus was found in an ovule collected at Lahore from a tree in the Gol Bagh on the 10th May 1930. Its abnormal external characters struck the writer as the material was being passed through the grades of alcohol. It was forthwith singled out and a detailed study of the internal structure was carried out in serial transverse sections which revealed some more points of interest in addition to its external morphology. (See plate X fig. 71).

External characters.—The prothallus was of the normal length *i.e.*, about 11 mm. It was much more compressed than a normal prothallus from the abaxial and the adaxial sides, the shorter and the longer diameters being 1.3 and 2.6 mm. respectively. When these measurements are compared with those of a normal prothallus which are 2.3 and 2.6 mm. the contrast comes out clearly. This prothallus was further peculiar in having all the archegonia aggregated towards one flat side (plate X fig. 71), the other flat side being quite devoid of archegonia. The archegonia were not situated at the extreme tip of the prothallus but some distance below. In a normal prothallus the archegonia are disposed radially around the micropylar end. The writer is not prepared to hazard a guess as to the position of the side bearing the archegonia *i.e.*, whether it was adaxial or abaxial because it was not noted at the time of the dissection of the prothallus preparatory to fixation.

Internal structure.—There were 11 archegonia according to one interpretation, or 12 according to another, borne by the prothallus. The largest number in this species, in normal prothallia, is 7. So far as the writer is aware the highest number of archegonia, which has been recorded for any species of *Pinus* is 9 (Ferguson 24, *P. montana* var. *uncinata*). In other species on which Ferguson worked she found that the highest number was 5 (24). In the writer's specimen as many as 9 could be counted in a single section. Owing to the large number of archegonia and the limited volume of the prothallus the archegonia were not oval as usual, but were compressed out of their shape by mutual pressure. The necks of all the archegonia opened on the side on which they were aggregated and not towards the apex as is generally the case. The longer axes of the archegonia did not coincide with the longer axis of the prothallus but they were either at right angles to or oblique to the longer axis of the prothallus.

Each archegonium possesses a distinct jacket all round. When the number of archegonia is small in a prothallus the space between different archegonia is filled with parenchymatous cells of the prothallus, but when the number is large the jacket cells of adjacent archegonia come into contact with each other but yet the identity of the two jacket layers is maintained. In this prothallus it was noted that in many cases there was no parenchyma between the jackets of adjacent archegonia which thus came into contact. Two archegonia were exceptional in having only one layer of jacket cells between them (plate X fig. 69).

In spite of such a large number of archegonia borne by the prothallus all of them were normal except one. Most of them showed different stages before, at and after fertilization. In fig. 69 the small male nucleus is seen in the egg cytoplasm in the left hand archegonium.

One of these archegonia was peculiar in having a bulge on one side (plate X fig. 69). This bulge appears in sections as a small archegonium with a jacket of its own. This jacket is distinct all round the so-called archegonium except at the place where it comes into contact with its larger neighbour, where there is only a thin membrane separating the two (plate X fig. 70). In sections taken at a lower level this membrane begins to disappear. Finally the membrane disappears altogether and the cytoplasm of the so-called archegonia is seen fusing (plate X fig. 69). At still lower levels the smaller bulge like structure disappears but its larger neighbour continues. It is at these lower levels that the persisting archegonium shows four nuclei of the pro-embryo. The bulge-like structure which does not extend throughout the whole length of the larger archegonium shows no nucleus and the writer was not able to see a definite neck attached to it.

Now there are only two ways in which this peculiar structure can be explained. Either it is in reality a bulge given off by the larger archegonium or it is itself an archegonium, which has got fused with its neighbour. The first alternative seems rather unlikely because there is such a large number of archegonia borne by the prothallus, that the possibility of a protrusion being given off by one of them is excluded on physical grounds. The other alternative appears to be more sound; though there are the following two serious objections to it:—Firstly, the smaller archegonium possesses no neck and secondly it shows no nuclei at all. The large number of archegonia and the resulting mutual pressure go in favour of the second alternative (*i.e.*, two adjacent archegonia have fused). It is also a fact, as noted above, that there are two archegonia, which have

got a common layer of the jacket cells between them. In this case the mutual pressure and the limited space available have resulted in the elimination of both the jacket layers between the two archegonia under consideration and the consequent fusion of the two archegonia. As to how the neck and the nucleus of the smaller archegonium disappeared remains unexplained. No traces of a disorganizing nucleus could be made out.

This prothallus agrees with the one described by Saxton (60) in *P. maritima*. In that prothallus the longer axes of the archegonia were at right angles to the longer axis of the prothallus and they opened laterally. The prothallus No. 1 described by the present writer stands alone by itself in the two fusing archegonia or the one bulging archegonium.

After the writer had found the female prothallus described above he kept a look-out for any other abnormalities. Both of the abnormal prothallia described below were collected on the 15th May, 1920.

Prothallus No. 2.

This prothallus bore only three archegonia which were laterally placed. Their longer axes were oblique to the longer axis of the prothallus. Their venters instead of their necks made acute angles with the longer axis of the prothallus. Their necks opened out towards the side and not towards the apex (plate X fig. 72).

Prothallus No. 3.

This prothallus was in reality a transitional stage between No. 2 and a normal prothallus. In this there were three archegonia; one was situated at the apex and opened apically, while the other two opened laterally. Plate X fig. 73 shows the prothallus as seen externally.

Conclusions.

The lateral position of the archegonia resembles that met with in *Araucaria* and *Agathis*, but their aggregation towards one side only resembles the condition met with in *Callitris*.

Seward and Ford (62) regard this feature in *Araucaria* and *Agathis* as a primitive feature, and Saxton (60) holds the same view in regard to *Callitris*. If the view of these writers is correct the occurrence of lateral archegonia in *Pinus* would be a sort of reversion to a primitive character and the prothallia Nos. 2 and 3 would represent the intermediate stages towards the realisation of the apical position of the archegonia. The view advanced by Saxton (60) in his note on *P. maritima*, that the lateral position may be of the nature of a mutation cannot be held in view of the transitional stages described by the present writer.

The disappearance of one layer of jacket cells between two archegonia where they touch points towards the origin of the archegonial complex in the *Cupressineae*. Coulter and Chamberlain (14) state that 'all the evidence of morphology, vascular anatomy and history favours the belief that the *Taxodineae* and the *Cupressineae* have been derived from the much more primitive stock of the *Abietineae*.' This view coincides well with the explanation offered above for the disappearance of one jacket layer between two archegonia, or the disappearance might have no phylogenetic significance, having resulted from purely mechanical causes.

VII. Abnormalities in the male cone-bearing shoots.

I.

Occasionally in the cluster of male cones, the writer found a few of the cones replaced by dwarf-shoots. From their position on the long shoots, the dwarf-shoots and the male cones are held to be homologous organs. The evidence from abnormalities further supports this conclusion.

II.

In one case the writer found that a branch after producing a number of male cones had divided. A number of male cones were borne by each of the two branches. A little higher up the branches had again fused and a number of male cones were borne on a single axis. Higher up still there was a single apical bud of young dwarf-shoots.

VIII. Summary.

In *P. longifolia* most of the lower branches bear clusters of male cones only. The female cones are found on branches high up in the tree. These branches bear only the female cones, and very rarely give rise to a branch which bears a cluster of male cones.

The male cones are initiated in September in Lahore. They grow continuously till pollen is shed in February. The female cones are initiated in January. After pollination which takes place in February the female cones close up but continue to grow till about May when they become about an inch in length and growth is stopped. A deep-seated megaspore-mother-cell is formed about the 18th or 20th of February. This undergoes a reduction division.

Only a few free nuclei are formed by the division of the functional megaspore before the resting period ensues in May. Growth is resumed in February next. Till the last week of March only a peripheral layer of cytoplasm with free nuclei is seen. The compact tissue of the female prothallus arises in the same way as in other Coniferales.

The fully formed female prothallus is a cylindrical body tapering towards the two ends (11-12 mm.). It is slightly compressed from the adaxial and the abaxial sides. Only the micropylar end of the prothallus bears the archegonia. The number of these may be between 2-7. The archegonium is about 1 mm. in length. Its neck shows 2 tiers of four cells each. The archegonia never come into direct contact.

The development of the archegonium agrees closely with those of the other Abietineae. The archegonial initials become visible in the first week of April in Lahore. The ventral canal cell is cut off in the usual way in the last week of April. The ventral canal nucleus shows signs of disorganization very early. The egg nucleus travels down to the centre of the archegonium and grows very rapidly in size. When fully grown its longer diameter measures 202.5 microns. Ordinary vacuoles in the egg cytoplasm get filled up and form what are called proteid vacuoles.

The fully formed archegonium before syngamy shows a receptive spot.

The pollen-tube discharges all of its contents into the archegonium through a pit. A large quantity of cytoplasm and some starch grains are also passed in.

On entering the archegonium the male nuclei slip out of the enveloping sheath of cytoplasm. The larger one moves towards the female nucleus and becomes lodged in the latter in a cavity towards its upper side. Syngamy in Lahore takes place about the 30th of April. In Chamba it takes place about the 1st of July. The first segmentation spindle is intranuclear. The two segmentation nuclei divide simultaneously. The four segmentation nuclei travel to the base of the archegonium, and become arranged in a single plane. All of these divide simultaneously. Vertical and cross-walls in the pro-embryo are formed immediately after this mitosis. The next division takes place in all the nuclei of the upper tier simultaneously. The last division takes place in all the cells of the lowermost tier simultaneously and the pro-embryo completes its development. The cells of the suspensor tier (second from below or third from above) begin to elongate and carry the embryo tier (lowermost) down into the female prothallus.

Some abnormal female prothalli are described.

Reduction divisions in the pollen mother cells have been followed by the smear method. The male cones are initiated in Lahore in September. By the middle of November the three or four wall-layers of the sporangium get defined. By the third week of January most of the cells of the sporophyll and the cells of the wall except the two

innermost layers get a deposit of a resiniferous substance. Demarcation of dehiscence in the sporangium occurs soon. The cells of a longitudinal plate of 3 or 4 cells towards the under side do not get this resiniferous substance and in the middle line of this plate of cells dehiscence takes place when the sporangium becomes ripe. A tapetum as a distinct layer is marked off rather very early when compared with the other species of *Pinus*.

Growth and division of the sporogenous cells are continuous and uninterrupted till the formation and the dispersal of the pollen grains. Pollen mother cells become recognizable in January. Reduction divisions take place during the last week of January and pollen grains are shed in the middle of February. There is no winter rest.

The pollen mother-cells are polygonal and show very large nuclei. The cytoplasm contains at first mitochondria but starch later on. During the prophase the nucleus undergoes the first contraction. Small starch grains make their appearance in the cytoplasm at this time and remain there throughout. Near the close of the first contraction a continuous thread can be made out in the synizetic knot. This thread uncoils itself and becomes peripherally distributed in the nucleus. The mother-cells become loose at this time. In the spireme a longitudinal split appears. The spireme shortens and thickens. The split becomes invisible. This is followed by the second contraction. On recovery from the second contraction the spireme shows a number of loops. The spireme gets segmented. Each segment corresponds to a pair of somatic chromosomes. It is believed that conjugation is telosynaptic. At the diakinesis stage chromosome tetrads become visible. During metaphase the spindle fibres are not so well developed. The bivalents separate into constituent univalents which move towards the spindle poles. They become somewhat longer at this time. They show longitudinal splits. In each of the two batches of chromosomes four very long chromosomes can always be detected. During early telophase the spindle fibres become very prominent. The chromosomes of the two groups gradually organize themselves into the typical resting nuclei. They form a continuous beaded thread. Branching in the chromosomes is brought about by vacuolation. No nucleoli appear in the daughter nuclei and an evanescent cell-plate is laid down between them. A constriction furrow appears between the two daughter cells during inter-kinesis but it does not separate the two daughter cells rapidly.

The second homotypic division is simultaneous in the two daughter cells. In the prophase a more or less continuous spireme is formed which segments into the reduced number of chromosomes. These chromosomes when they lie on the equator of the spindle are

pretty long and therefore this metaphase presents a sharp contrast to the preceding metaphase of the heterotypic division. During the anaphase the chromosomes move to the poles of the spindle and become bent. The two batches of chromosomes form the two daughter nuclei. The chromosomes are thin and the telophasic changes are brought about by branching. An ephemeral cell-plate is formed after telophasic changes. The cleavage furrow laid down between the daughter nuclei of the previous heterotypic division develops still further. A second furrow appears between the grand-daughter nuclei and so the mother-cell cleaves into four parts. Opposite the furrows thickenings are laid down in the wall of the mother-cell. These grow centripetally in between the furrows and the mother-cell becomes quadripartitioned.

Twelve bivalents have been counted at the diakinesis stage, so the haploid and the diploid numbers of chromosomes are 12 and 24 respectively.

The male gametophyte consists of two lenticular cells which disorganize very soon. They cannot be made out in pollen grains at the time of shedding.

The male cones and the dwarf shoots in *Pinus* are believed to be homologous organs. This conclusion is supported by the evidence afforded by abnormalities met with in the clusters of male cones, where some of them may be replaced by dwarf shoots.

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X. Explanation of Plates.

All the microscopic figures with the exception of photomicrographs have been drawn with a camera lucida.

PLATE I.

- Fig. 1. Photograph of a tree.
 Fig. 2. A branch showing female cones of 4 generations.

PLATE II.

- Fig. 3. Fully formed resting megaspore-mother-cell. $\times 3325$.
 Fig. 4. Nucleus of the megaspore-mother-cell showing the spireme during the prophase of the first heterotypic division. $\times 400$.
 Fig. 5. Nucleus of the megaspore-mother-cell during the synizesis stage. $\times 2355$.
 Figs. 6, 7. Formation of the bivalent chromosomes in the nucleus of the megaspore-mother-cell (heterotypic division). $\times 2355$, 3325 .
 Fig. 8. Archegonial initial. $\times 800$.
 Fig. 9. Archegonial initial. Older stage than Fig. 8. $\times 800$.
 Fig. 10. The archegonial initial has divided into the primary neck cell and the central cell. $\times 800$.
 Fig. 12. Central cell dividing to produce the ventral canal cell and the egg. $\times 640$.

PLATE III.

- Fig. 13. Nucleus of the central cell before division lying just below the neck. $\times 800$.
 Fig. 14. Later stage in the division than that shown in Fig. 12. $\times 800$.
 Fig. 17. Proteid vacuoles being filled up. $\times 650$.
 Fig. 18. Egg showing receptive spot. $\times 120$.
 Fig. 20. Egg cytoplasm with a large quantity of cytoplasm passed from the pollen tube. $\times 220$.
 Fig. 23. A reconstruction of Fig. 22 showing all the nuclei. $\times 120$.
 Fig. 25. First segmentation spindle. $\times 800$.
 Fig. 27. One of the two segmentation nuclei dividing. $\times 1690$.

PLATE IV.

- Fig. 28. Four segmentation nuclei. (Only three are visible).
 Fig. 29. Four segmentation nuclei arranged at the base of the archegonium. $\times 650$.

- Fig. 30. First division in the nuclei of the pro-embryo (only one is seen). $\times 650$.
 Fig. 31. Pro-embryo showing four upper nuclei and four lower cells. $\times 650$.
 Fig. 32. Pro-embryo showing division in the nuclei of the upper tier. $\times 650$.
 Fig. 33. Pro-embryo showing three tiers. $\times 650$.
 Fig. 34. Pro-embryo showing early suspensor formation. $\times 650$.

PLATE V.

- Fig. 11. Archegonium before the cutting of the ventral canal cell.
 Fig. 15. Egg nuclei are seen travelling down towards the centre of the archegonia. The ventral canal cells are also visible.
 Fig. 16. A mature egg nucleus.
 Fig. 19. The end of the pollen tube is seen between the female prothallus and the nucellus. The two male nuclei are embedded in a common sheath of protoplasm.
 Fig. 21. Two male nuclei are seen in the egg. The female nucleus is below.
 Fig. 22. The male nucleus is seen approaching the female and the latter has produced a projection towards the former.
 Fig. 24. The male nucleus is lodged in a concavity of the female nucleus.
 Fig. 26. Two segmentation nuclei.

PLATE VI.

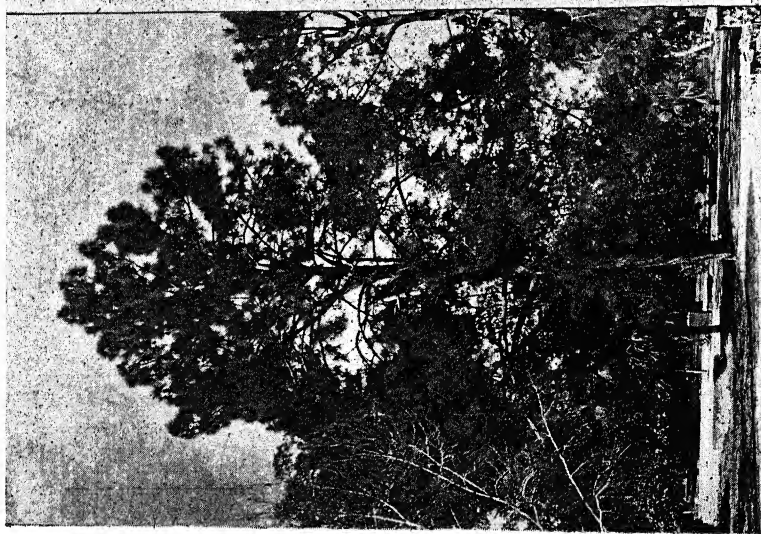
- Fig. 35. Cross section of microsporangium. All the cells of the wall are filled with resin except those between which dehiscence takes place.
 Fig. 36, 37. Pollen mother-cells. $\times 2350, 3325$.
 Fig. 38. Early prophase. $\times 3325$.
 Fig. 39. Later than Fig. 38. $\times 2350$.
 Fig. 40. Synizesis. $\times 3325$.
 Fig. 41. Close of synizesis. A continuous chromatic thread can be seen within the synizesis knot. $\times 3325$.
 Fig. 42. Chromatic thread uniformly distributed within the nucleus. $\times 3325$.

PLATE VII.

- Fig. 43. Spireme split at certain places. $\times 1690$.
 Fig. 44. Second contraction. $\times 1690$.
 Fig. 45. Ditto. $\times 1690$.

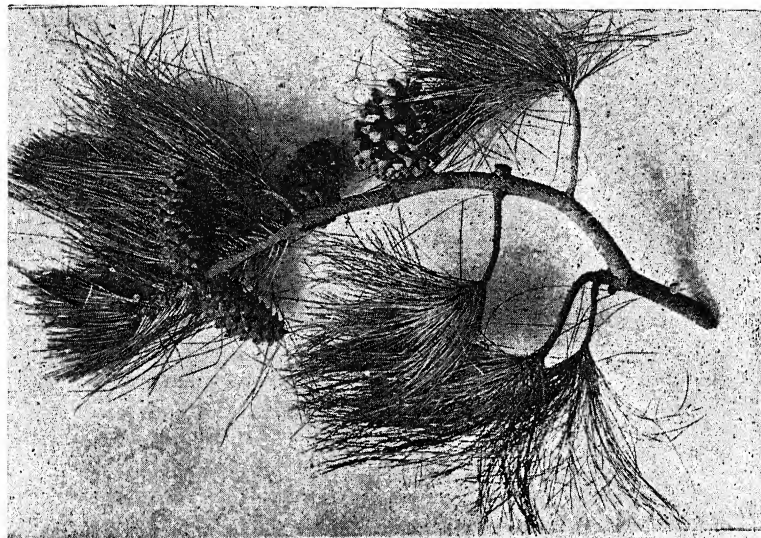
SETHI: PINUS LONGIFOLIA.

Plate I.

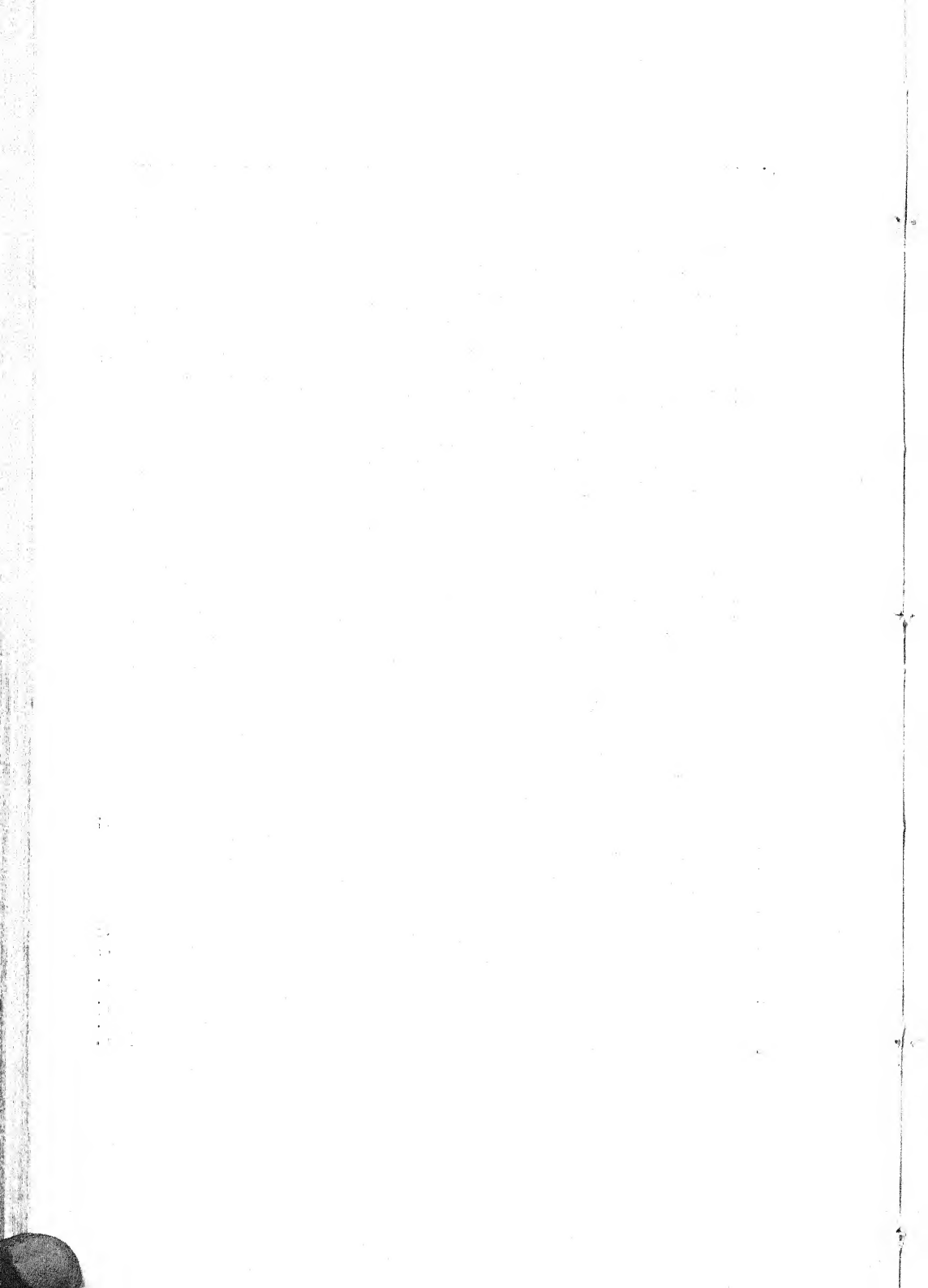


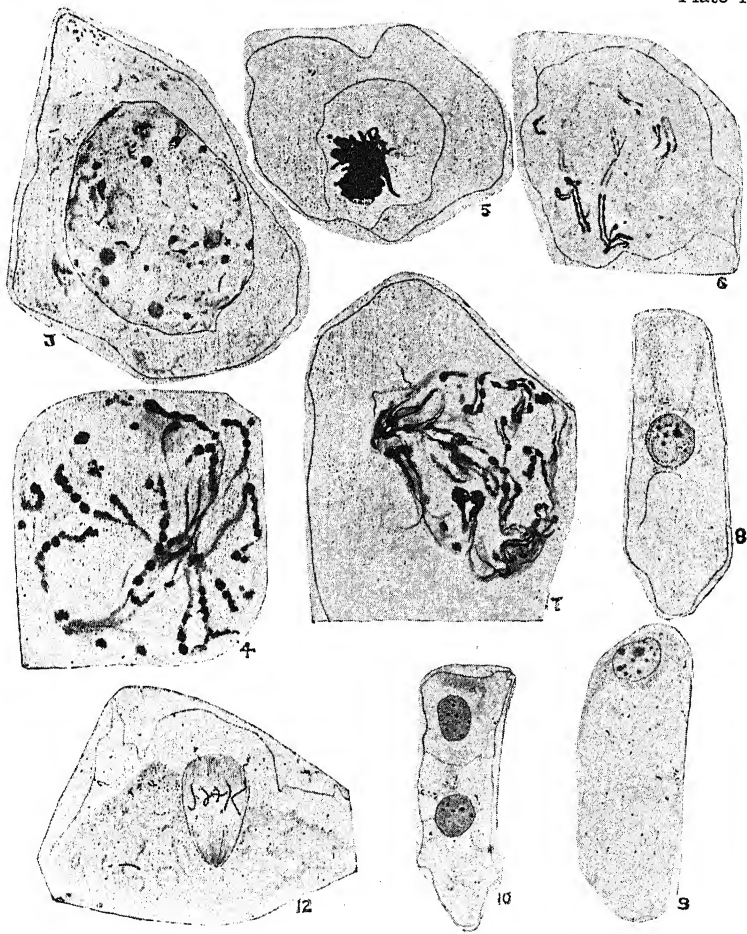
M. L. S. Phot.

1.



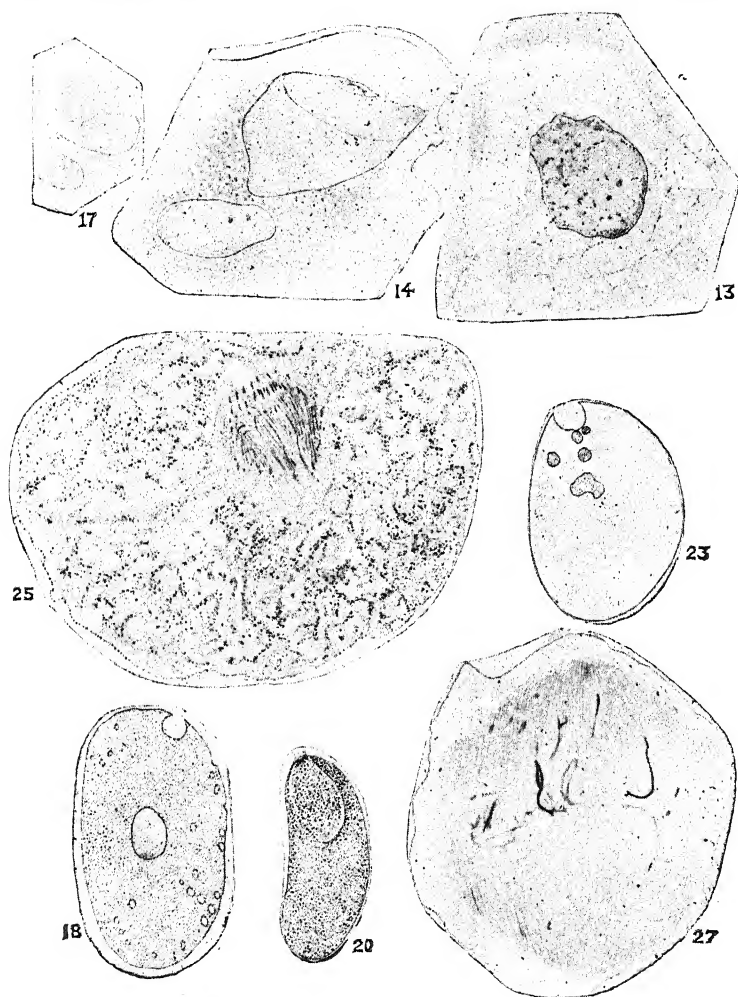
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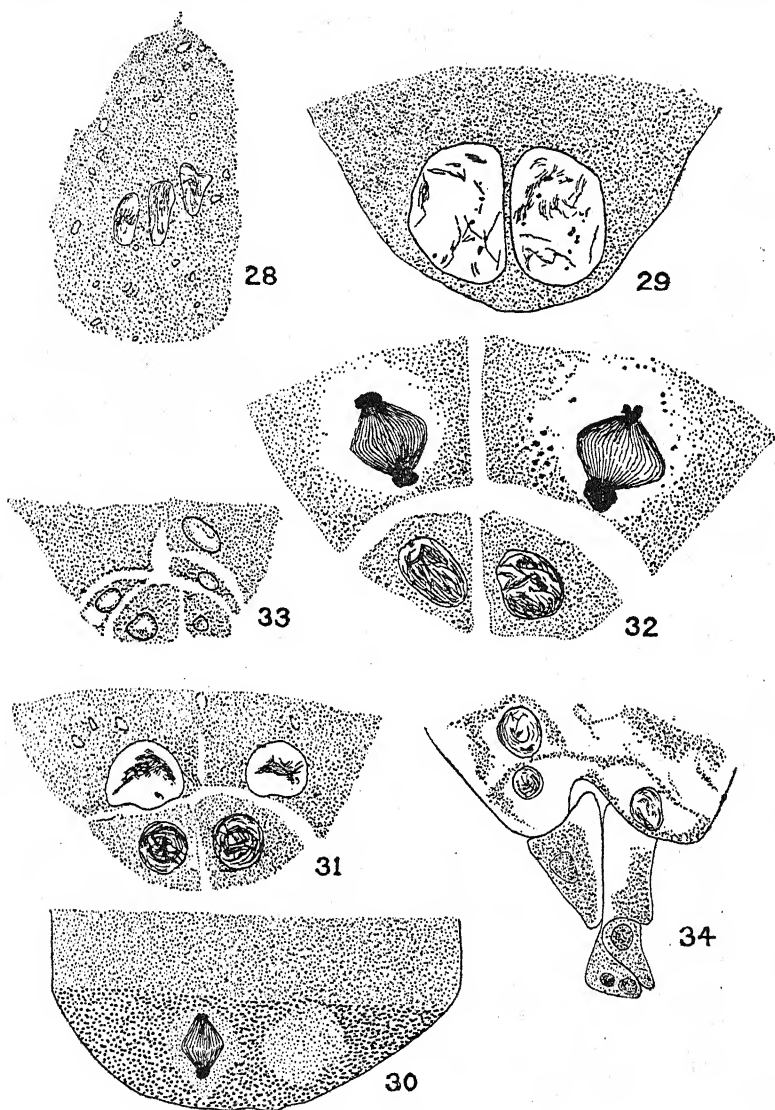


Figs. 8—10, 12.

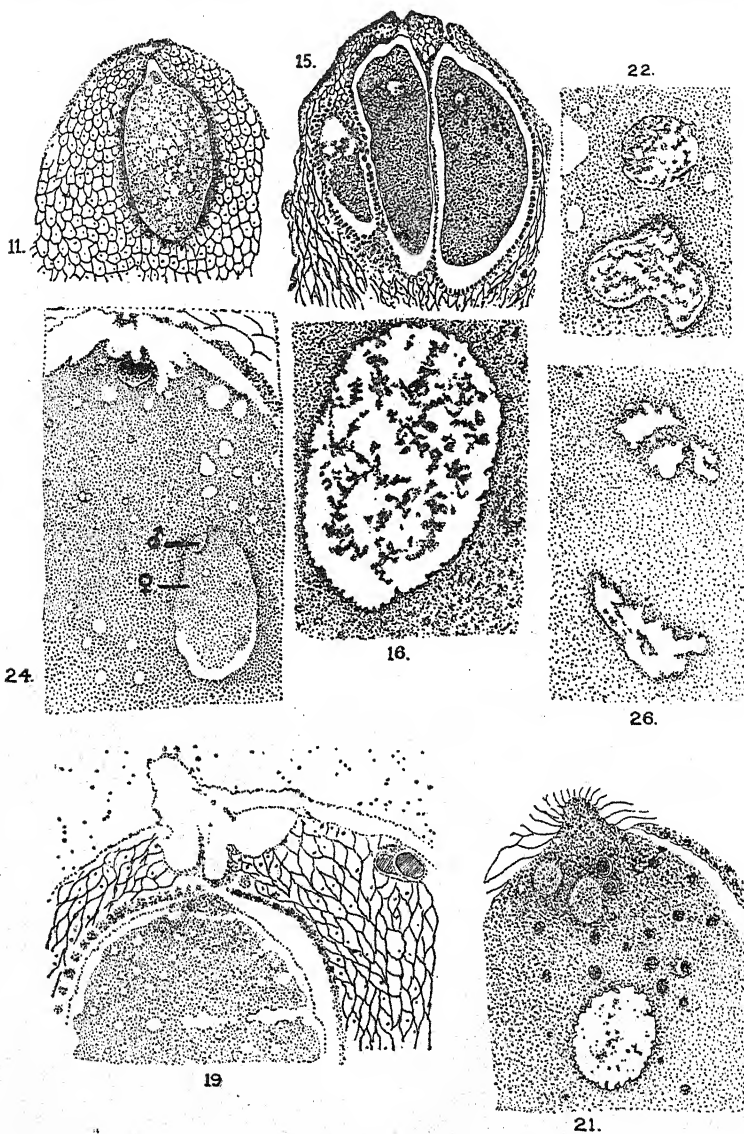




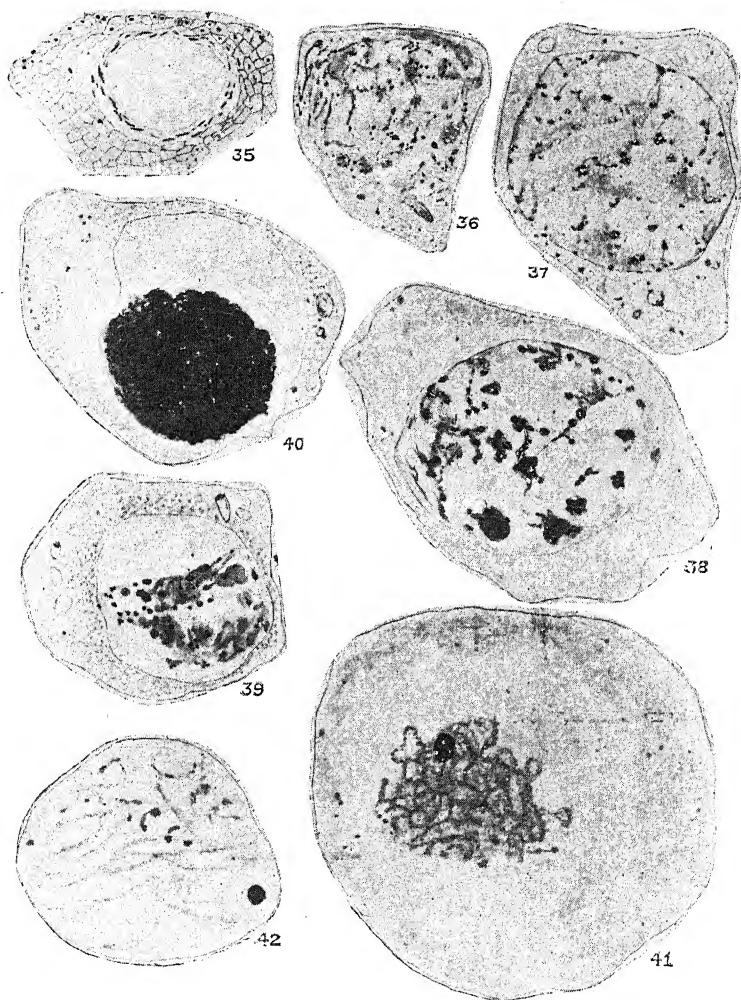
Figs. 13, 14, 17, 18, 20, 23, 25, 27.



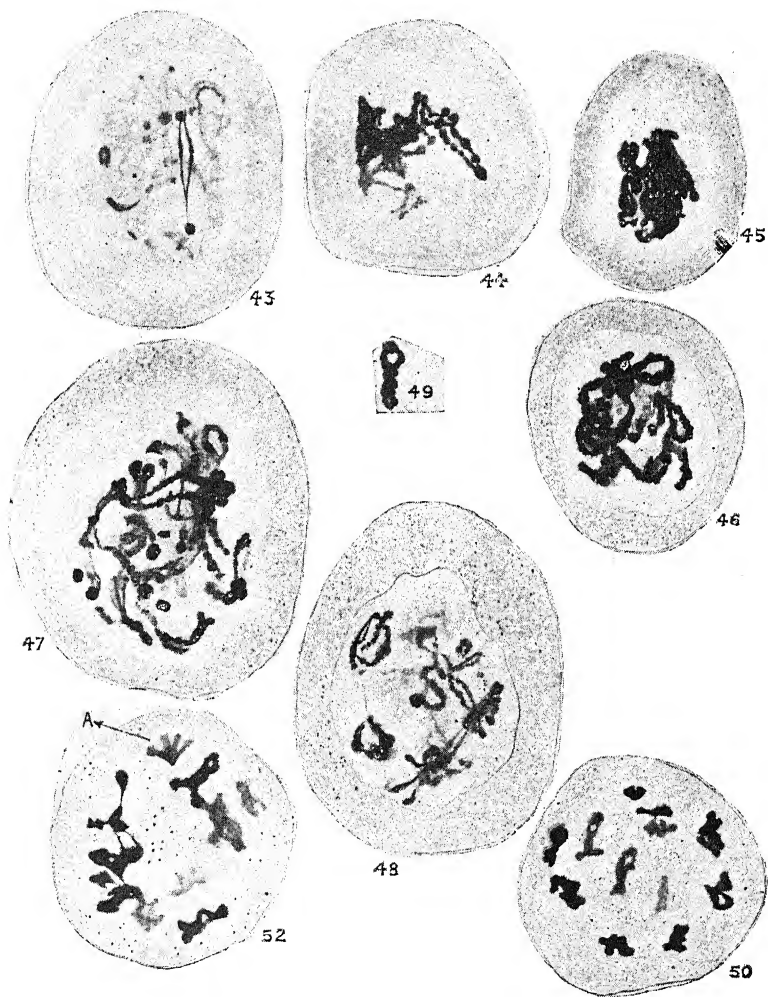
Figs. 28-34.



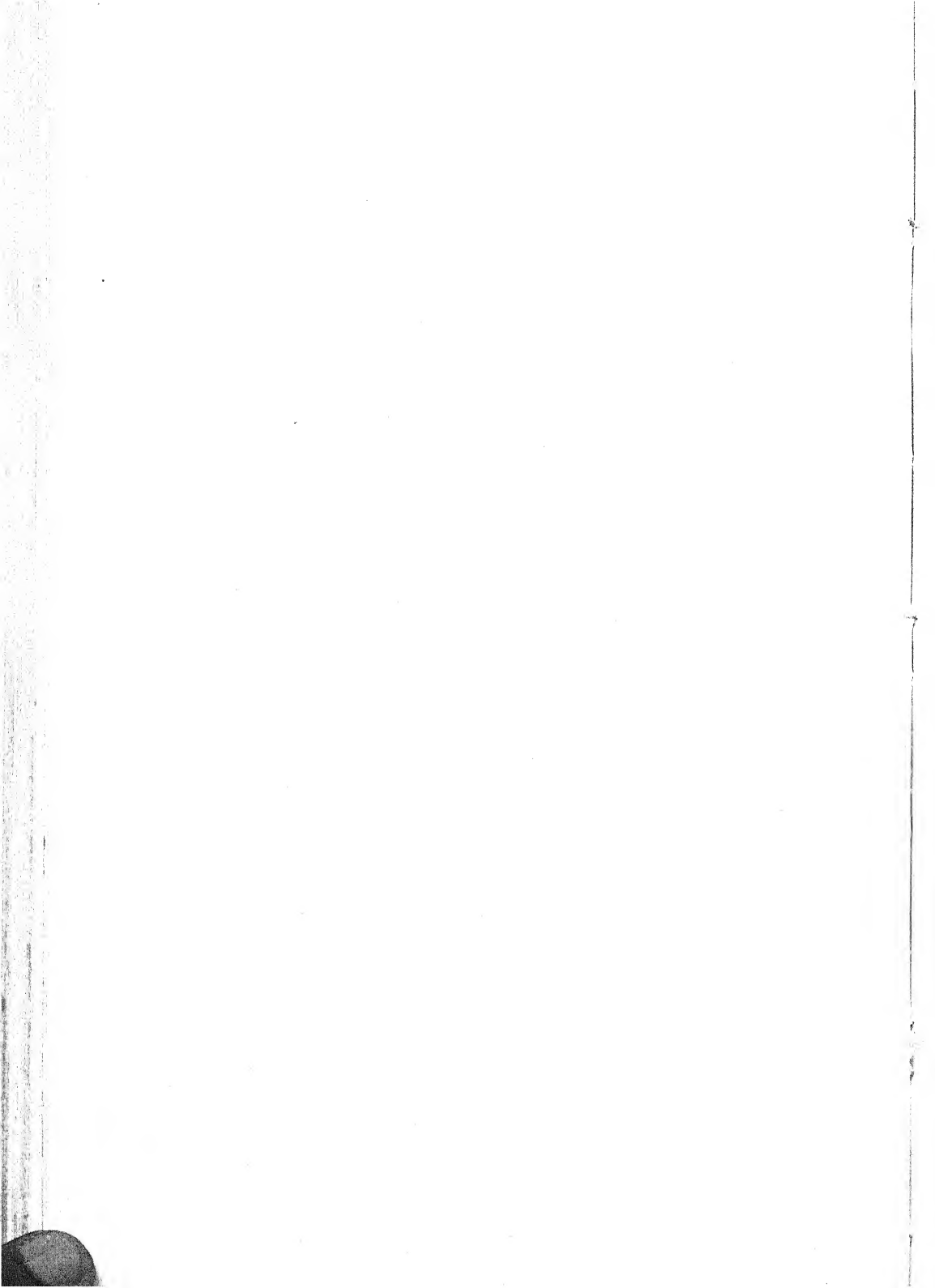
Figs. 11, 15, 16, 19, 21, 22, 24, 26.

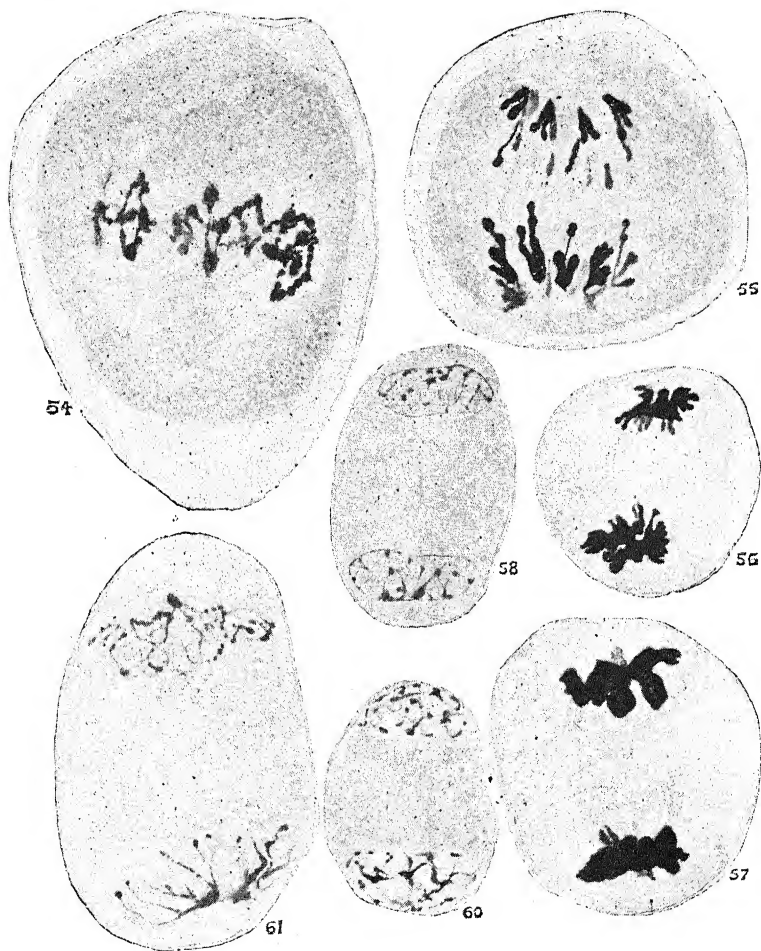


Figs. 35-42.

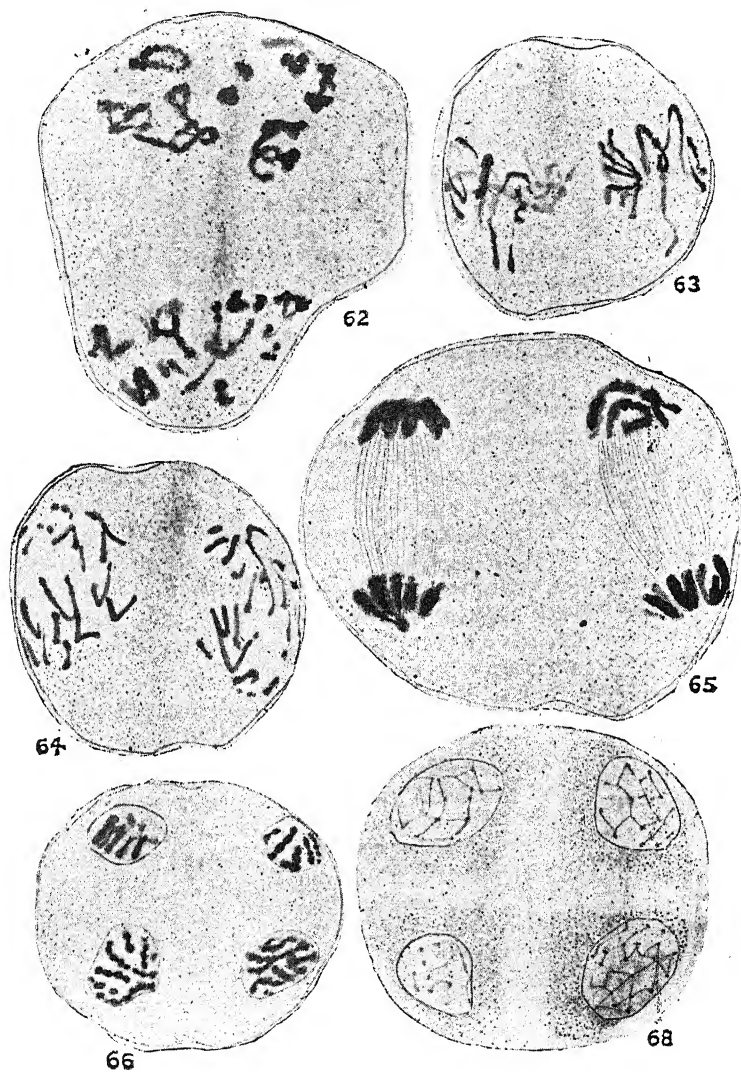


Figs. 43—50, 52.

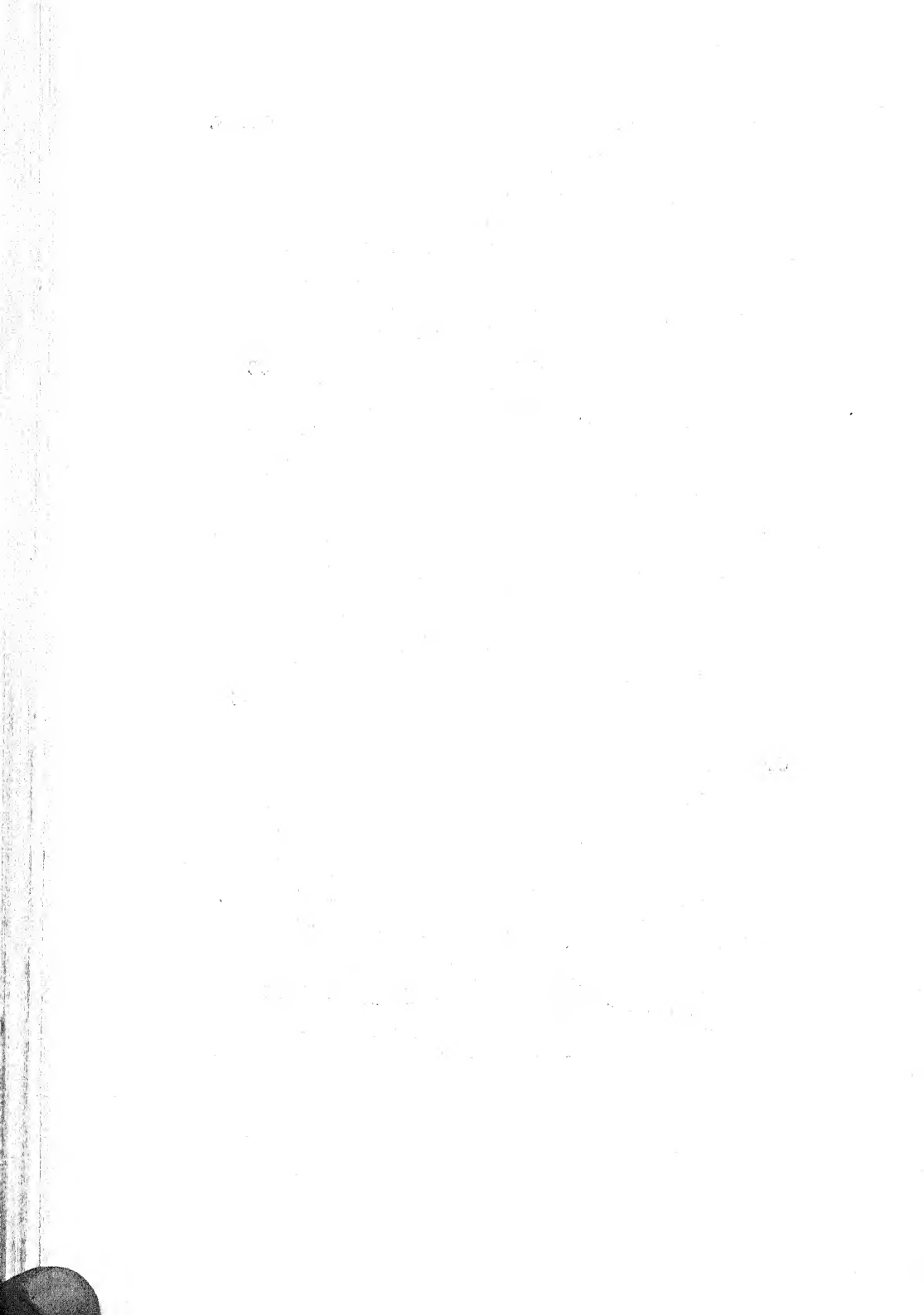


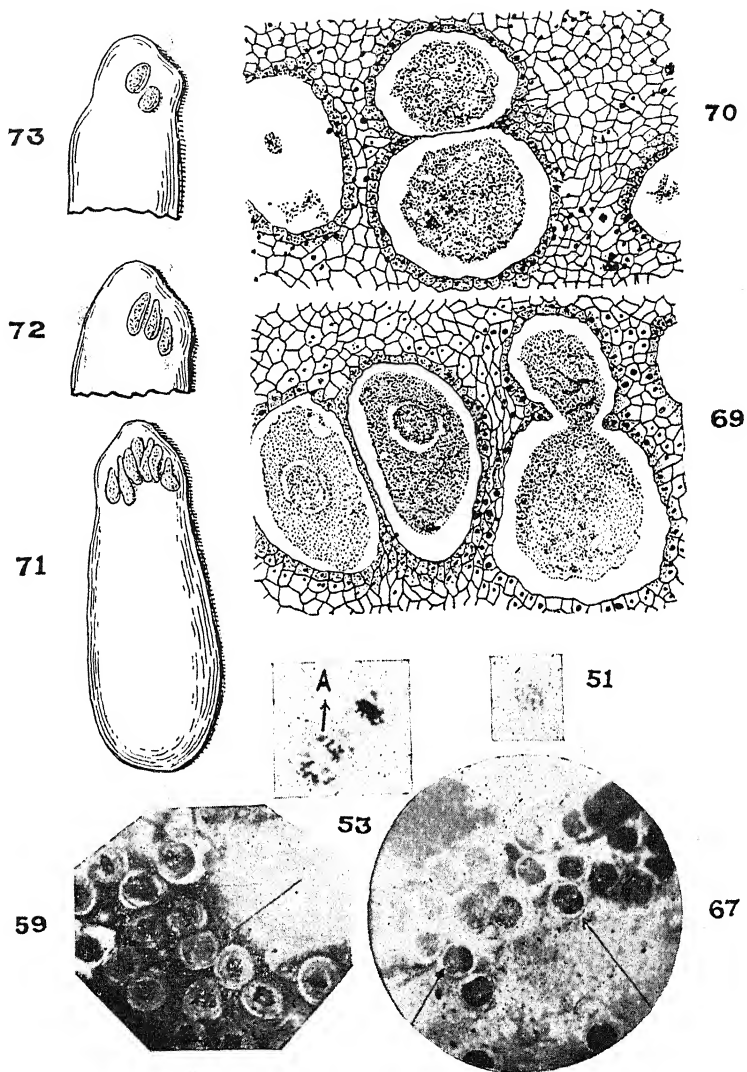


Figs. 54—58, 60, 61.

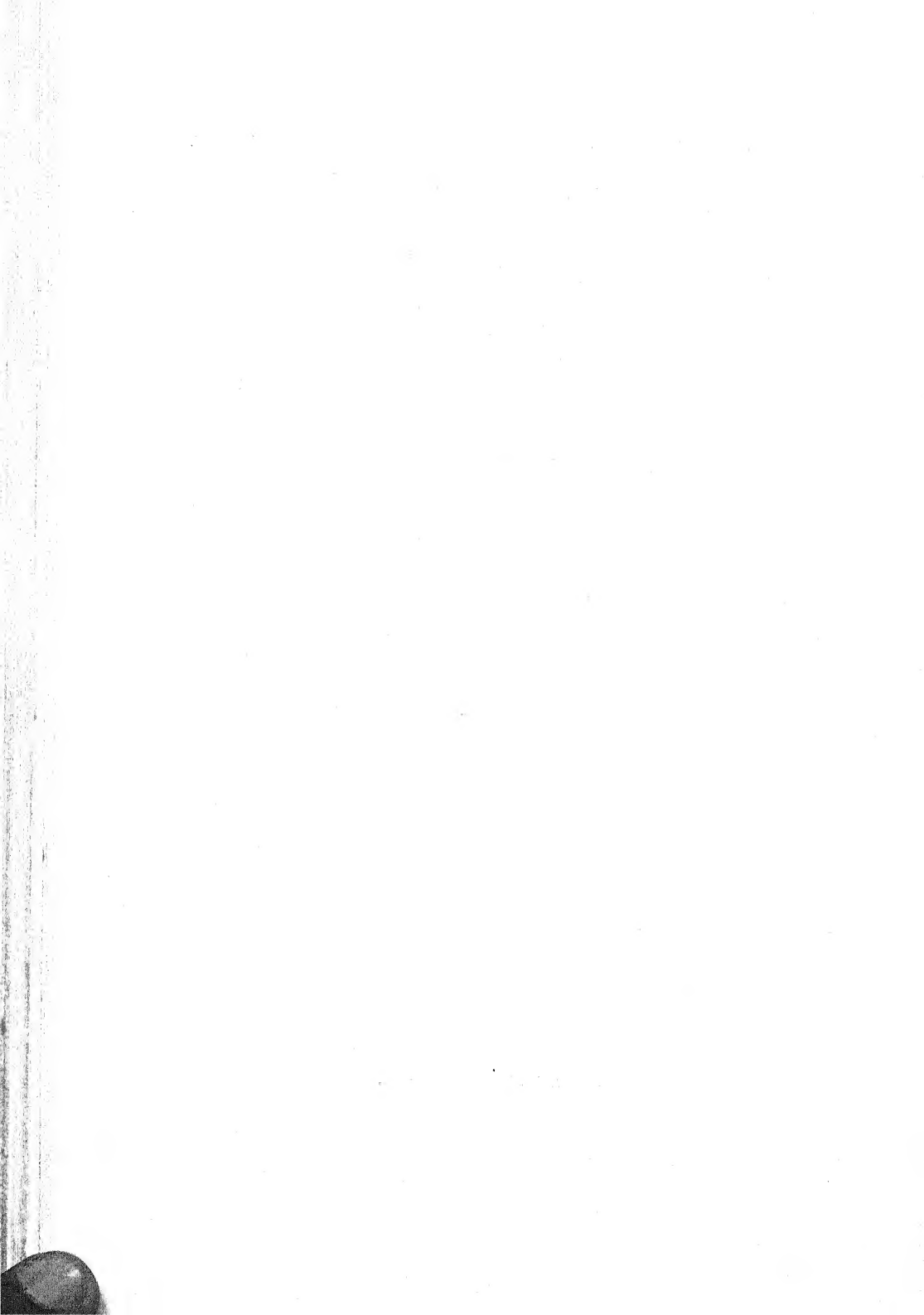


Figs. 62-66, 68.





Figs. 51, 53, 59, 67, 69-73.



- Fig. 46. Recovery from second contraction. $\times 1690$.
Figs. 47 and 48. Complete recovery from second contraction. $\times 2350, 2350$.
Fig. 49. Bivalent showing univalents (strepsinema). $\times 2050$.
Fig. 50. Diakinesis showing 12 bivalents. $\times 1690$ (cf. photomicrograph in plate X Fig. 51).
Fig. 52. Diakinesis showing chromosome tetrads. $\times 1660$ (cf. photomicrograph in plate, X Fig. 53.)

PLATE VIII.

- Fig. 54. Metaphase just before anaphase. $\times 3325$.
Fig. 55. Anaphase. $\times 2350$.
Fig. 56. Late anaphase or early telophase. $\times 1690$.
Fig. 57. Late telophase. 2350.
Fig. 58. Resting nuclei in the daughter cells at the end of the heterotypic division. $\times 1690$.
Fig. 60. Early prophase of the second homotypic division. $\times 1690$.
Fig. 61. Later prophase of the second homotypic division. $\times 2350$.

PLATE IX.

- Fig. 62. Prophase of the second division showing fully formed chromosomes. $\times 2350$.
Fig. 63. Metaphase of the second division showing fully formed chromosomes. $\times 1690$.
Fig. 64. Anaphase Ditto. $\times 1690$.
Fig. 65. Early telophase Ditto. $\times 2350$.
Fig. 66. Later telophase Ditto. $\times 1690$.
Fig. 68. A tetrad. $\times 2050$.

PLATE X.

- Fig. 51. Photomicro. of the cell shown in Fig. 50.
Fig. 53. Photomicro. of the cell shown in Fig. 52.
Fig. 59. Photomicro. showing daughter cells at the end of the heterotypic division. No cellplate can be seen.
Fig. 67. Photomicro. showing mother-cells with furrows.
Fig. 69. T. S. Abnormal prothallus No. I. One archegonium has a bulge on one side.
Fig. 70. T. S. Abnormal prothallus No. I showing two archegonia separated by a thin membrane only.
Fig. 71. Abnormal female prothallus No. I. $\times 6$.
Fig. 72. " " " No. II. $\times 6$.
Fig. 73. " " " No. III. $\times 6$.

INJECTION-EXPERIMENTS ON PLANTS

BY

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It struck me why injection-methods being more direct were not largely tried to combat physiological or fungus diseases of plants or to help their growth. In March 1922, I began injection-experiments on a number of chlorotic pot plants of *Crinum asiaticum* by injecting a 0.5% solution of ferrous sulphate into their bulbs with a hypodermic steel needle. The basal end of the needle was connected by means of a rubber tube with a graduated glass tube fixed on a stand at some height from the ground (see fig.), so that the level of the solution in the tube was kept higher than the point of insertion of the needle and thus the solution could enter by means of a continuous upward pressure for a number of days. The quantity absorbed daily was noted. The results were not quite conclusive and the work was interrupted for a time as I had to leave India for Europe. After my return, I was repeating the experiment in December 1924, when my attention was directed to the work of Dr. C. B. Lipman of the University of California, (*Journal of General Physiology* May 20, 1924, Vol. VII, No. 5, pp. 615—623), who cured a number of chlorotic and diseased *Citrus* trees by injecting a large quantity of ferrous sulphate solution into their trunks; the method adopted was identical to that used by me; it took about three months to restore the normal green appearance of the trees.

In April 1925, I noticed some yellow *Mimosa* plants (*Mimosa pudica*) growing in the open among a large number of green healthy plants and apparently suffering from chlorosis, in the Bose Research Institute at Calcutta. All leaves (with their leaflets) of affected plants looked yellow. Evidently, there was no deficiency of iron in the soil as the neighbouring *Mimosa* plants so close by were completely green. Possibly, it was a case of injury to the roots and root-hairs of affected plants by coming in contact with hard bricks underground, as has been found by Dr. R. Marloth in the course of his investigations into the causes of the chlorotic condition of fruit trees in the Wellington District (Univ. South Africa. Dept. Agric. Sci. Bull. 29. 21p. 6 pl.—1924).¹ Marloth has recorded that about 5,000 trees in

¹ I have seen this paper in abstract in Bot. Abstracts, July—Nov. 1926.

the region were affected, the roots alone indicating a diseased condition, some of which might be due to mechanical injury in cultivation.

Very dilute solution of ferrous sulphate (25%) was injected into the stem of the plant in its own habitat by means of a hypodermic steel needle attached to a graduated glass tube by means of rubber

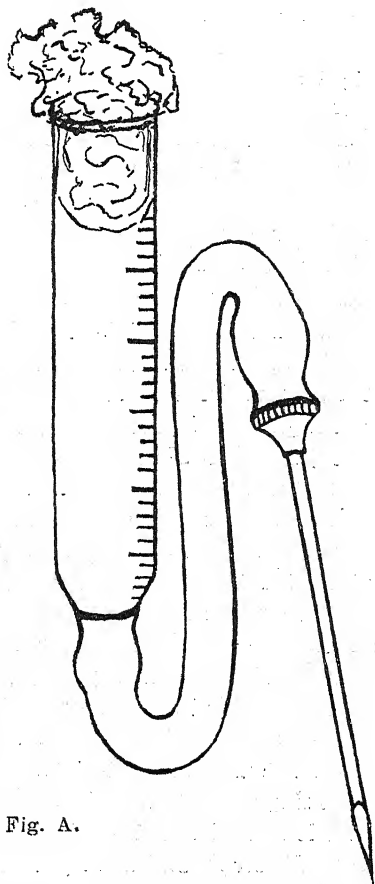


Fig. A.

tubing, following exactly the same method as I did in case of the bulb of *Crinum asiaticum*. The glass tube was filled with a 25% solution of ferrous sulphate, a few drops of machine oil were poured on the surface of the solution to prevent evaporation, and the needle was kept on for a number of days, the solution getting in by means of a continuous upward pressure. The daily record of the quantity absorbed was kept by noting the level of the liquid. In the course of

even three or four days I was surprised to find that all the leaflets of the plants turned completely green; the treated plant could hardly be distinguished from the normal green plant. I repeated the experiment on more than a dozen such chlorotic plants, and in each case the result was the same. In some plants the response was quicker, in two days the whole plant turned green. Of course, the rate of absorption varied depending on various external factors and individual requirements of plants. The quantity absorbed in the first twenty-four hours varied from .3c.c. to 1.5c.c. in different plants. Two things had to be guarded against in such experiments,—the choking of the narrow bore of steel needles, and the leaking out of the solution from the joints. The needle had to be inserted right into the wood of the stem—into the circulating current of the growing plant, taking care to exclude entrance of air. The corresponding strengths of the solution (Fe SO_4) were poured on the soil round the yellow *Mimosa* plants which were watched for a number of days; but the response was very feeble and almost negative.

While renewing the experiment of injection of very dilute solution of Fe SO_4 into stems of *Mimosa pudica* in June 1925, my attention was directed to the fact that most of iron in the solution was precipitated on the sides of the graduated glass tubes in the form of brownish deposits, being oxidised, and that what actually passed into the plants was thin clear acidulated water ($\text{H}_2 \text{SO}_4$ solution) containing a very minute trace of iron (much lower than .25% solution). This led me to omit the iron solution altogether and to inject very faintly acidulated water (1 mim. of sulphuric acid in 100 cc. of water) with steel needles into stems of a new set of chlorotic *Mimosa* plants. In the course of five to six days (comparatively little longer time than that in the first case), the whole plant turned beautifully green; it was repeated on a number of yellow *Mimosa* plants; in each case the result was the same. The details of the rate of absorption in each case from day to day were recorded. The treated and cured plants were watched for more than a year; there was not a single case of reversion amongst them. It was found by the colorimetric method that the acidulated water in contact with the steel needle dissolved out a very minute trace of iron (0.00025% ionised iron), which was entering the plant along with the streaming solution.

As a sort of control, glass needles (hard and narrow capillary glass-tube ground to a fine point in the form of a needle) were used instead of the steel ones, and the experiments repeated on a fresh set of chlorotic *Mimosa* plants in the Bose Research institute in August and September 1926, with the same acid-water alone (1 mim. Merck's pure sulphuric acid in 100 cc. of water). It was found that the response

was very feeble and unsatisfactory, there was no perceptible change in the course of a fortnight though about 2 cc. of the acid-water were absorbed during the time.

Next, I tried similarly injection of the same acid-water with a steel needle into the stem of some stout medium-sized *Ixora coccinea* with yellow leaves, growing from the ground. In the course of eleven days the whole stalk with sub-branches turned green; of course, the total quantity of water absorbed was greater than that in the case of *Mimosa* plants.

A stray case of sudden conversion of a number of chlorotic *Mimosa* plants into normal green ones immediately after a heavy shower of rain was noticed in our college garden-fields (February 1926); possibly, the circulating stream of the rain-water had the effect of somehow modifying the power of absorption of affected plants in this instance.

By using the very delicate test of Macallum for the detection of minute traces of iron, as described by Prof. Benjamin Moore in Proc. Royal Society, Vol. 87 (1914), pp. 556—571, it has been found that the amount of iron in a healthy leaf is much greater than that in a chlorotic leaf; and from the colorimetric method it appears that the quantity of iron in healthy plants (either in stems or roots) is almost double the quantity in chlorotic plants, and that the amount of iron is always greater in stems than that in roots. For this estimation I am indebted to my friend Dr. H. N. Mookherjee, B. Sc., M.B., D.I.C., of the Bio-Chemistry Department of our College.

Apart from the general scientific interest attached to the restoration of the green colour of chlorotic plants, the injection-method might be used with advantage in the case of feeding starved fruit-trees, and this direct method of feeding might prove a great improvement on the natural method of providing the tree with its sustenance through the soil by means of fertilizers.

Since writing most of this paper, my attention was directed to the work of Messrs. Hopkins and Wann (Bot. Gazette Vol LXXXIV, No. 4, December 1927, pp. 423—426) where it is stated that "it is not the total amount of iron in the culture medium, but the amount in the ionised form which is effective physiologically. Therefore, while we may have a larger total amount of iron present, we may have little or no growth because of a low concentration of the ferric ion." This probably explains that the iron-ion-concentration necessary for the conversion of chlorotic *Mimosa* plants into normal green ones is infinitesimally small.

THE ORIGIN AND EVOLUTION OF THE ARCHEGONIUM *

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Introduction

Perhaps the greatest gap which we find in the evolutionary study of the plant kingdom, is the one that exists between the Thallophytes and those groups of higher plants which are collectively called the Archegoniatae.¹ Not long ago a similar gap was supposed to exist between the Bryophytes and the Pteridophytes because of the difference in the relative degree of development of the *X* and the *2X* generation and other reasons. This gap has now been greatly bridged by the discovery of the group Psilophytales,² which in some respects

* Dissertation (prepared during the tenure of my Research Studentship at the Lucknow University) accepted for the Woodhouse Memorial Prize, 1927.

¹ The term Archegoniatae has been employed throughout this paper to include the Gymnosperms also.

² Kidston, R. and Lang, W. H. (1917-21): On Old Red Sandstone Plants, showing structure, from the Rhynie Chert-bed, Aberdeenshire. Parts I-V, *Trans. Roy. Soc., Edinburgh*, Vols. 51, 52.

presents intermediate characters. The problem in regard to the Thallophytes and the Archegoniatae chiefly concerns the presence of a well defined sporophytic generation in the Archegoniatae and the relation of the sexual organs in the two groups. The presence of a well defined sporophytic generation gives less difficulty because in recent years, studies of the Thallophytes have indicated the possibility of a very general tendency towards the development of a sporophyte in this group. But the problem of the relation of the sexual organs in the two groups, or more precisely the origin of the archegonium and antheridium of the Bryophytes is still unsolved, because these organs have no clear parallel in the sexual organs of the Thallophytes. Views, however, have been expressed from time to time suggesting the possible derivation of these organs from the sexual or asexual reproductive organs of different members of the Thallophytes, but so far no conclusive statement seems to have been made on the subject. In the following pages the writer has attempted to review in brief the most important views expressed by different authors on the origin of the archegonium, and a suggestion has been made to derive this organ from the oogonium of *Coleochaete*. A further attempt has been made to discuss the evolutionary changes that are observed to have taken place in this organ in different groups of the Archegoniatae, of which it is so characteristic a feature. The evolution of the archegonium, as will presently be shown, probably means largely a process of retrogression directly dependent upon the land habit.

The Origin of the Archegonium: Previous Views

Before attempting to elaborate any original idea on the subject, it seems advisable to summarise critically the two most important views, expressed respectively by Götz and Davis.

Götz's View.

In *Chara* there are certain small cells called by Götz Wendungszellen which are cut off from the egg before maturity. The significance of these cells, was not fully known before. Götz¹ put forth his view that "they stand for the walls of a reduced archegonium," thus "regarding" the female sex organ "as a degenerate archegonium plus the enveloping whorl of filaments that surround the egg and forms the crown." Davis, however, differs from him and has expressed his opinion, with which I agree that, "This is a very interesting suggestion, although objections present themselves in the complexity of the process required to bring about the degeneration of

¹ Götz, (1899): Ueber die Entwicklung der Eiknospe bei den Characeen. *Bot. Zeit.* lvii. 1.

such a well-established organ as the archegonium and its displacement by an equally elaborate envelope of filaments.¹ About the accessory cells (Wendungszellen), he says that, "they may be nothing more than the final and somewhat irregular expression of the vegetative activities of a growing point that is about to become transformed into a sexual organ."

Davis' View.

Davis, however, derives the archegonium from the multicellular gametangia found in a number of the lower members of the Phaeophyceae, e.g. *Ectocarpus*. He thinks that two sets of factors, one influencing the structure, the other influencing the sexual character of the cells, must have acted to bring about the required change.

Regarding the structural modifications of the gametangium, according to Davis, the most important one which would be effected concomitant with the adoption of the terrestrial habit would be the sterilization of the outer layer of gamete-mother-cells, forming an enclosing capsule. While, on the other hand, as regards the character of the sexual cells he considers that the first step would be the establishment of heterogamy and then the development of the differentiation of activity, and finally the retention of the egg within the gametangium².

Dr. Church, however, differs from Mr. Davis and has remarked in his book "Thalasssiophyta," "The analogy of an archegonium with a plurilocular sporangium was considered by Davis (1903) with very imperfect data, and little progress seems possible along these lines."³ He is of opinion that the origin of the archegonium must be sought for in the transmigrant phyla, as the result of the transition to the new environment. The following few lines quoted from his book give a summary of his view about the origin of the archegonium. "It may be granted that the archegonium, so long regarded as the distinctive attribute of the "Archegoniatae" is clearly an end product of oogamic evolution, the limiting term of something quite unknown, probably originating in something quite different from any recent archegonium, and if we saw it, scarcely recognizable as such. Very probably again of polyphyletic origin, arising in phyla of marine algae of quite diverse descent, and convergent in general factors, as the limiting term of a

¹ Davis B.M., (1903): Origin of Archegonium, *Ann. of Bot.* Vol. 17, p. 477.

² For a series of diagrams illustrating the possible evolution of the archegonium and antheridium from the plurilocular sporangia, see Davis, B.M. (1903).

³ Church, A. H., (1919): *Thalasssiophyta and the Subaerial Transmigration*, pp. 12-14. *Oxford*.

special mechanism; at bottom no necessary guide to affinity, but merely indicating that the "Archegoniatae" may be the expression or a number of phyla at the same physiological horizon in this particular respect."

Apart from Dr. Church's criticism, it may be remarked that there has been a general tendency among botanists to regard the Chlorophyceae rather than the Phaeophyceae or the Rhodophyceae, as helpful in tracing the evolution of the higher plants. Among the green algae, the greatest plasticity of form and structure is found in the Isokontae which according to West and others includes the progenitors of the higher plants.¹ Even Davis seems a little sceptic about his view when he says that, "The lower Phaeophyceae" with plurilocular sporangia "can hardly be supposed to have given direct origin to the Bryophytes although this is conceivable."² In fact he derives the Bryophytes from a hypothetical extinct group of Chlorophyceae with plurilocular sporangia. Therefore while searching for a type which would possess a female sexual organ nearly resembling an archegonium, it is natural to look for it among the green algae with special reference to Isokontae.

*A Suggestion to Derive the Archegonium from the
Oogonium of Coleochaete.*

A searching study of the Chlorophyceae seems to show that the female sex organ of *Coleochaete* is more suggestive of an archegonium than any which we have studied so far. Although it is true that the procarpium of *Callithamnion* has some resemblance to the archegonium, but we will not hold discussion on that organ any further and would reject it on the same ground as the plurilocular gametangium of the Pheophyceae. The female sex organ of *Coleochaete* is known as the oogonium. It is a unicellular flask-shaped body with a long neck which opens at the tip when mature, to allow the entrance of spermatozoids. The egg is situated in the lower swollen part of the oogonium. In general appearance the oogonium looks very much like an archegonium and if we compare it with a mature archegonium of the Liverworts the lowest evolved group among the Bryophytes—the most striking difference is seen in the absence of a multicellular wall.

The development of the multicellular wall can very well be attributed to an adaptation to the terrestrial habitat, that is to meet a demand for protection against desiccation. Besides the multicellular wall we have a varying number of neck-canal cells and a ventral-canal cell, in the archegonium of a Liverwort, while the oogonium

¹ West, G. S., (1915) : *Algae* (Cambridge University Press), p. 158.

² Davis, B. M. (1903) ; *Origin of the Archegonium, Ann. of Bot.* Vol. 17, p. 492.

of *Coleochaete* is a unicellular structure. We know that when the archegonium becomes mature its neck-canal and ventral-canal cells degenerate and their contents becoming mucilaginous exude out of the neck and diffusing in the water present outside, exert an attractive stimulus on the spermatozooids. Not only in the Liverworts but even in the Bryophytes as a whole and also the Pteridophytes, the ventral-canal and the neck-canal cells have the same function. Thus it seems quite clear that the ventral-canal and the neck-canal cells have no other function to perform in the process of fertilization except ultimately of serving to attract the spermatozooids after being converted into some sort of chemotactic mucilaginous substance. It will be shown in the following paragraphs that the development of these extra cells besides the oosphere (egg) in an archegonium, has been a direct result of an adaptation to the terrestrial habitat.

When the migration from water to land took place the chances for the act of fertilization naturally became less, as for example in the case of amphibious plants (*viz.* the Bryophytes, etc.) the fertilization had to be carried out in the presence of only a little amount of water and that also was not always available, so there was less chance of the spermatozooids reaching the egg. In order to meet this deficiency in the chance of fertilization, some means had to be evolved by the migrating plants. This deficiency might be said to have been met by the production of some chemotactic substance through the disintegration of the neck-canal and ventral-canal cells of the mature archegonium.

We also know cases where the egg and the ventral canal cell cannot be distinguished one from the other in a mature archegonium, at least so far as size is concerned, for example in *Fossombronia longiseta*,¹ *Porella Bolanderi*,¹ *Anthoceros*,¹ *Notothylas* sp.,² *Notothylas orbicularis*,¹ *Ophioglossum pedunculatum*,¹ *Marattia Douglasi*,¹ *Pinus Laricio*,³ etc. And in *Pinus Laricio*, it is interesting to note that they are not distinguishable until after fertilization. In abnormal cases the ventral-canal cell in an archegonium may even behave as an egg in addition to the normal one already present. Then there are also cases known in which the egg, ventral-canal and neck-canal cells may all be alike in size *e.g.* in *Porella Bolanderi*.¹ Besides all these evidences from the mature

¹ Campbell, D.H., (1913): Mosses and Ferns. p. 93. fig. 44; p. 108, fig. 54 F.; p. 127, fig. 66 A & p. 134; p. 151, fig. 81 A. & p. 151, fig. 82 D.; p. 233, fig. 123 F.; p. 280, fig. 153 C.

² Mottier, D.M., (1894): Contribution to the Life-history of *Notothylas*. *Ann. of Bot.* Vol. 8, p. 399.

³ Coulter, J. M. and Chamberlain, C.J., (1925); *Morphology of Gymnosperms*, p. 267.

archegonia represented from different circles of affinity, we have the developmental study of the archegonium in which it is clearly seen that in every case all the cells whether ventral-canal or neck-canal are cut off from a single one. With these data before us, it will not be unnatural to regard the neck-canal and ventral-canal cells to have probably been formed in phylogeny by being cut off from an ancestral egg when the migration to land was taking place. If we agree to what has been said above we can derive the archegonium from the oogonium of *Coleochaete* by encapsulation in order to meet the demand for protection against desiccation, and by the cutting off of neck-canal and ventral-canal cells from the egg, these cells on disorganisation forming some mucilaginous substance which exerted an attractive force on the spermatozoids, to meet the deficiency of water for the act of fertilization.

In support of the view put forth the writer has to offer the following arguments:—

(1) "The Confervoideæ among the Green Algæ are for good reasons considered to be among living forms, the nearest to the progenitors of the Archegoniataæ. Among the Confervoideæ, *Coleochaete* most nearly approximates to the condition found in the lower Bryophytes." ¹ If the *Coleochaetes* are nearest to the progenitors of the Archegoniataæ as stated above by Campbell then the writer's view as to the derivation of the archegonium from the oogonium of *Coleochaete* will probably not appear unwarranted.

(2) As we approach nearer and nearer to the siphonogamic mode of fertilization, we find that the motility of the sperms is gradually lost and that they are bodily carried to their destination (the egg) by the pollen-tube. Concomitant with this feature the neck-canal and the ventral-canal cells being no longer needed (after disintegration) to attract the spermatozoids, decrease in number till all of them are eliminated as we see in some Gymnosperms e.g. *Podocarpus*. Thus it is quite clear that the ventral-canal and the neck-canal cells are chiefly concerned with the attractive movements of the spermatozoids.

(3) That the development of the multicellular wall of the archegonium is chiefly to meet the demand for protection against desiccation, is shown by the fact that in those plants in which the archegonium lies embedded in the prothallus and consequently has a secure position it loses the identity of its walls and may be said to have no wall at all as there is no difference between the cells surrounding the egg cell and the cells of the prothallus.

¹ Campbell, D.H., (1918): Mosses and Ferns, p. 563.

The Evolution of the Archegonium

Comparative Study of the Archegonium

We shall now attempt to trace the general tendency in the evolution of the archegonium. The most important characters in this connection are, the variation in the number of the neck-canal cells, the ultimate elimination of the ventral-canal cell and lastly the position of the archegonium on the female gametophyte. We shall therefore take up the consideration of these three characters group by group. The chart given below contains a summary of the more important characters of the archegonia in nine genera selected from the Bryophytes.

A. Bryophyta.

Genera	Ventral C. Cell	Neck C. Cells	Neck Cell	Position on the prothallus
<i>Targionia</i> ...	1	8	60-80	Projecting on the prothallus
<i>Fossombroniat.</i>	1	4-6	many	do.
<i>Porella</i> ...	1	5	do.	do.
<i>Aneura</i> ...	1	4-6	do.	Partly embedded.
<i>Riccia</i> ...	1	4	do.	Situated in a cup-shaped [cavity.]
<i>Sphaerocarpus</i>	1	2-4	do.	do.
<i>Anthoceros</i> ...	1	4	do.	Embedded.
<i>Funaria</i> ...	1	5	do.	Projecting.
<i>Sphagnum</i> ...	1	many	do.	do.

Discussion : A general survey of the archegonium in the Bryophytes shows that most members of this group have superficial archegonia. This character is naturally regarded as a primitive one. In *Aneura* the base of the archegonium is confluent with the thallus and in this respect it offers an easy approach to the condition found in *Anthoceros*, where the sterile cells of the archegonia being embedded lose their identity in the tissue of the gametophyte. Besides these few variations, the general structure of the archegonium is quite constant throughout the phylum. The number of the neck-cells is very variable and is more numerous in the Mosses than in the Liverworts. It will be seen later that no phylogenetic stress can be laid on this character.

The two most important points, which deserve mention in this connection are, firstly, the variation in the number of the neck-canal cells, and secondly, the position of the archegonium in relation to the female gametophyte. It will be shown in the succeeding pages that the reduction in the number of the neck-canal cells and the embedded condition of the archegonia in the gametophyte, are criteria of higher evolution. If these be granted for the time being we would see that *Anthoceros*—with 4 neck-canal cells (with the exception of the *Sphaerocarpus*) and the embedded condition of its archegonia—among the Bryophytes would be the most nearly related to the Pteridophytes. In fact its partially independent sporophyte is selected as illustrating a possible ancestral condition of the vascular plants at the level of the Bryophytes.

Further Dr. Campbell, in a recent paper on the sporophyte of *Anthoceros fusiformis*, Aust.¹ has brought out certain very interesting points which in addition to other facts show similarity of certain recondite characters in common with the Devonian Rhyniaceae, thus binding the Bryophytes and the Pteridophytes in a closer bond of relationship. For the sake of clearness a summary from Dr. Campbell's papers is reproduced below :—

"The discovery that the sporophyte of *Anthoceros fusiformis* under certain conditions, may become practically independent and the ability of these plants to develop photosynthetic and conducting tissues commensurate with their needs, is a very strong argument in favour of the antithetic theory of alternation of generations in the Pteridophytes".^{1, 2}

"The very close resemblance between the large sporophytes of *Anthoceros fusiformis* and the Devonian Rhyniaceae warrants the assumption of a real relationship between the latter and the Anthocerotales."³

"The existing Pteridophytes are almost certainly of polyphyletic origin, but all might be traced back to similar, but not necessarily closely related ancestors. The ancestral forms had sporophytes similar in structure to that of *Anthoceros*."³

¹ Campbell; D.H., (1924): A Remarkable Development of the Sporophyte in *Anthoceros fusiformis*, Aust. *Ann. of Bot.* Vol. 38, pp. 472-483.

² Campbell, D.H., (1925): The Relationship of the Anthocerotaceae. *Flora order Allgemeine Botanische Zeitung: Neue Folge*, 18 and 19 Band; (der ganzen Reihe 118 und 119 Band) S. 63-74.

³ Campbell, D.H., (1925): The Relationship of the Anthocerotaceae. *Flora order Allgemeine Botanische Zeitung: Neue Folge*, 18 and 19. Band; (der ganzen Reihe 118 und 119 Band). S. 63-74.

B. Pteridophyta.

Thirteen types have been examined, the result of which is summarised in the chart given below :

Genera	Ventral C. Cell	Neck-Canal Cells	Neck Cells	Position on the pro- thallus.
<i>Equisetum</i> ...	1	$\left\{ \begin{array}{l} E. debile \text{ 1} \\ \text{other spp. 2} \end{array} \right.$	$\left\{ \begin{array}{l} 4 \\ 4 \end{array} \right.$	$\left. \right\}$ Projecting.
<i>Psilotum</i> ...	1	...	24	do.
<i>Lycopodium</i> .	1	many	10-16	do.
<i>Selaginella</i> ...	1	one	2	Embedded.
<i>Isoetes</i> ...	1	$\left\{ \begin{array}{l} \text{one with 2} \\ \text{nuclei} \end{array} \right.$	$\left. \right\}$ 4	Partly embedded.
<i>Ophioglossum</i> .	1	do.	4	Embedded.
<i>Botrychium</i> ...	1	do.	4	Projecting.
<i>Marattia</i> ...	1	do.	3-4	Embedded.
<i>Onoclea</i> ...	1	do.	5-7	Projecting.
<i>Osmunda</i> ...	1	one or two	6	do.
<i>Gleichenia</i> ...	1	...	...	do.
<i>Marsilia</i> ...	1	$\left\{ \begin{array}{l} \text{one very} \\ \text{small} \end{array} \right.$	$\left. \right\}$ 2	Embedded.
<i>Pilularia</i> ...	1	do.	2	do.

Discussion : The number of ventral-canal cells is always one and that of the neck-canal cells never goes higher than four except in the case of Lycopods in which there are many neck-canal cells and in this respect they resemble the Bryophytes. In the Filicales the number of the neck-canal cells is reduced to one, the nucleus of which sometimes divides into two but no wall is formed between them. Thus we see that the general tendency among this group has been to reduce

the number of the neck-canal cells and among the Filicales the reduction has reached the stage of a single uninucleate cell. (In the Gymnosperms even this has disappeared). The number of neck cells varies from about two to sixteen. The heterosporous members of the group have reached the two-celled-neck stage which is generally seen among the Gymnosperms. In most of the cases considered, the archegonia are embedded in the tissue of the gametophyte as we saw in *Anthoceros*. It is remarkable that the heterosporous members of Pteridophytes have the archegonia on the climax of reduction. Among the species of *Equisetum*, *E. debile*¹ seems in this respect, to be the most advanced one, there being only one neck-canal cell as against two in the other species. Among the species of *Lycopodium*, *L. cernuum* occupies a similar position, with only one neck-canal cell.

C. Gymnosperms.

Genera or Families	Ventral Canal Cell	Neck Canal Cells	Neck Cells	Position on the prothallus.
<i>Cycas</i> ...	Only nucleus	nil	2	Embedded.
<i>Ginkgo</i> ...	one small cell	do.	2	do.
<i>Abietineae</i> ...	one cell or only a nucleus	do.	2-8	do.
<i>Taxodineae</i> ...	Only ephemeral nucleus	do.	2-8	do.
<i>Cupressineae</i> ...	do.	do.	2-8	do.
<i>Taxineae</i> ..	Even nucleus may not be cut off	do.	2-25	do.
<i>Podocarpaceae</i> ...	do.	do.	2-6	do.
<i>Ephedra</i> ...	Only nucleus	do.	32✓	do.

Discussion: The above chart dealing with the more important characters of the archegonia amongst the Gymnosperms, brings forth the conclusion that the general tendency among the Gymnosperms

¹ Kashyap. S. R., (1914): Prothallus of *Equisetum debile*. *Ann. of Bot.* Vol. 28, pp. 163-181. *Postscript.*—Since the above was written Sethi (*Ann. of Bot.* Vol. 42 p. 732 figs. 7-8) has shown that the number of neck-canal cells in this species is two, and not one as reported by Kashyap.

seems to be to eliminate the ventral-canal cell. Among the living forms so far known, a walled ventral-canal cell is retained only in the *Abietineae* and *Ginkgo*. In the other living groups the wall has disappeared altogether and the ventral-canal cell is represented only by a free nucleus. In certain forms even this nucleus has disappeared *e.g.*, in some members of the *Taxaceae*. The neck-canal cell has been completely eliminated from the *Gymnosperms*. The number of neck-cells shows a good deal of variation. In *Ephedra*, the neck is the longest known among the *Gymnosperms*, the minimum number of neck-cells being 32. Next lower in the scale come some member of the *Taxineae* which may have as many as 25 neck-cells and the two-celled neck is an established feature of the *Cycadales*, the *Ginkgoales* and some of the *Pinaceae*. The latter condition at first sight may be regarded as advanced, so far as that character is concerned, but there is so much variation in the number of the neck-cells even within a genus (*e.g.*, in *Torreya taxifolia* there are 2-3 neck-cells but in *T. californica* the number varies from 4 to 6) that no definite phylogenetic importance can be attached to that feature.

We do not find any archegonium in *Welwitschia*, the embryo-sac has two to five-nucleated cells in its micropylar region and all the nuclei in a cell are potential egg nuclei. In *Gnetum* the embryo sac at the time of fertilization contains only free nuclei and each one of them is potentially an egg nucleus. Thus we see that in these two members of *Gymnosperms* the last traces of the archegonium are being lost and *Gnetum* approximates to the condition found among the *Angiosperms*.

Summary.

(1) The views put forth by Davis and Götz, on the origin of the archegonium have been briefly dealt with and criticised.

(2) A suggestion to derive the archegonium from the oogonium of *Coleochaete* (by a process of encapsulation) has been put forth and discussed. As far as known to the author, this view is being advanced for the first time.

(3) It is suggested that the multicellular wall and the neck and ventral canal cells were produced in response to the terrestrial conditions, the first as a safeguard against desiccation and the second to meet the deficiency of water for the act of fertilization.

(4) The further evolution of the archegonium has been chiefly a process of reduction and of retrogression of the essential organ, the egg-cell, into the tissues of the gametophyte.

Acknowledgments.

In conclusion I feel it my pleasant duty to express my indebtedness to Professor B. Sahni (Lucknow University) for his criticisms and suggestions and also for the great interest which he kindly took in reading through the manuscript; to Mr. T. C. N. Singh (Institute of Plant Industry, Indore) for his invaluable critical advice and help during the course of the preparation of the manuscript; and to Mr. A. G. Dobbs (late Director of Agriculture, Bihar and Orissa) for his kindly obtaining permission from the Woodhouse Memorial Trust for the publication of this thesis.

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THE FLORA OF THE INDUS DELTA

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PART VI.

(Continued from p. 96, Vol. VII, No. 2).

C. SOME ECOLOGICAL NOTES

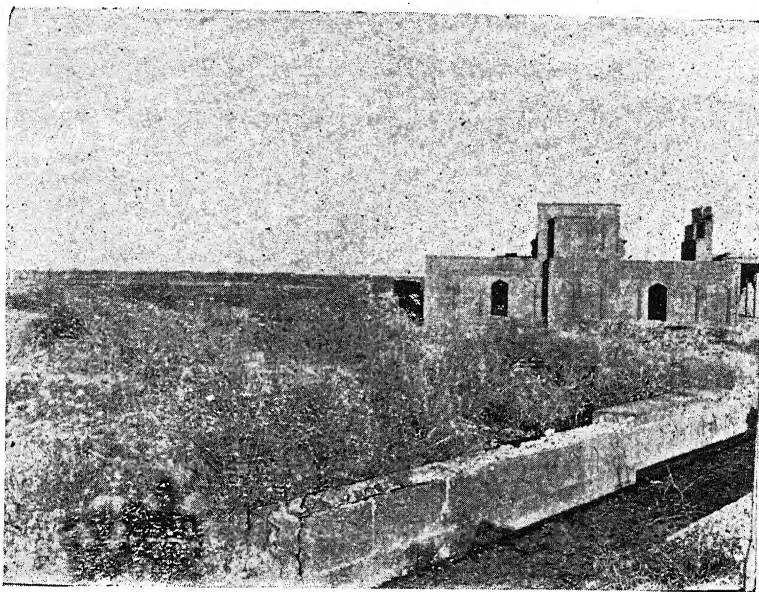
As we had not sufficient time at our disposal for prolonged investigations into the plant-ecological conditions of the Delta, we can only offer a few notes which may be of use to future visitors to that country. We are not going to describe the aspect and adaptations of the various formations or their members, as we already possess a rich botanical literature on the subject.

1. Gharo is a small village situated on the Gharo Creek between Dabheji railway station and Mirpur Sakro:

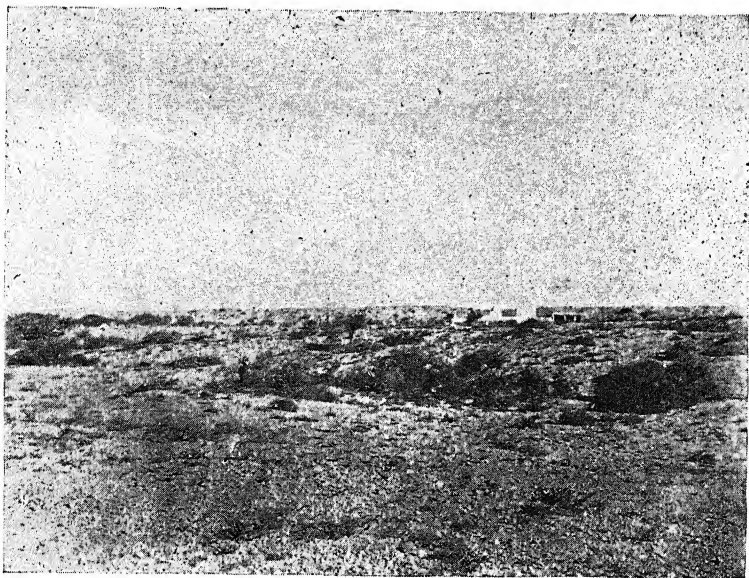
(a) On sand and sand-dunes to the north of the village: *Fursetia Jacquemontii*, *Cleome brachycarpa* var. *glauca*, *C. viscosa*, *Cadaba indica*, *Capparis decidua*, *Tamarix dioica*, *Launaea chondrilloides*, *L. nudicaulis*, *Leptadenia spartium*, *Convolvulus scindicus*, *Ipomœa biloba*, *Cistanche tubulosa*, *Aerva tomentosa*, *A. pseudo-tomentosa*, *Aristolochia bracteata*, *Ephedra foliata*, *Asparagus gharoensis*, *Cyperus arenarius*. (III. Nos. 1, 28.)

(b) On gravelly soil: *Polygala irregularis*, *Portulaca oleracea*, *P. quadrifida*, *Sida grewoides*, *Corchorus antichorus*, *Gossypium Bakeri*, *Tribulus terrestris*, *T. alatus*, *Fagonia cretica*, *Zizyphus rotundifolia*, *Crotalaria Burhia*, *Indigofera paucifolia*, *I. viscosa*, *Ocimum prophetarum*, *Citrullus Colocynthis*, *Nerium odorum*, *Heliotropium undulatum*, *H. paniculatum*, *Convolvulus Rottlerianus* var. *tenella*, *C. microphyllus*, *Solanum albicaule*, *Withania somnifera*, *Lycium barbarum*, *Euphorbia pilulifera*, *E. jodhpurensis*, *Cenchrus catharticus*, *Sporobolus arabicus*, *Aristida funiculata*, *Desmostachya cynosuroides*, *Chloris villosa*, *Eleusine flagellifera*, *E. aristata*.

(c) In silt or on silt-banks along the creek: *Tamarix Troupii*, *Acacia arabica*, *A. Senegal*, *Salvadora oleoides*, *Cressa cretica*, *Suaeda fruticosa*, *Haloxylon recurvum*, *Aeluropus villosus*. (III. Nos. 3 and 4.)



No. 41. A pure formation of *Lycium barbarum* in the Tatta Tombs area.



No. 42. Limestone hills near Gholam; *Gymnosporia montana*, *Grewia villosa*, *Prosopis spicigera*, *Mimosa hamata*, *Acacia Senegal*, *Periplocasp.*

(d) In the neighbourhood of wells: *Bergia odorata*, *Phyllanthus Niruri*, *Coix Lachryma-Jobi*, *Cymbopogon Jwarancusa*, *Panicum antidotale*.

(e) In crevices of lime-stone rock or on rocks: *Grewia populi-folia*, *G. villosa*, *Melhanian Denhamii*, *Commiphora Mukul*, *Tephrosia tenuis*, *T. petrosa*, *Orygia decumbens*, *Inula grantioides*, *Pulicaria Stocksii*, *Statice Stocksii*, *Pentatropis cynanchoides*, *Blepharis sindica*, *Ruellia patula*, *Barleria Prionitis*, *B. acanthoides*, *Salvia aegyptiaca*,

(f) Ruderal: *Abutilon muticum*, *Zygophyllum simplex*, *Coccinia indica*, *Trianthema monogyna*, *Solanum xanthocarpum*, *Linaria ramosissima*, *Lindenbergia urticaefolia*, *Amarantus polygamus*, *Achyranthes aspera*, *Polygonum plebejum*, *Euphorbia pilulifera*.

(g) Cultivated near village: *Thespesia populnea*, *Azadirachta indica*, *Zizyphus jujuba*, *Parkinsonia aculeata*, *Prosopis spicigera*, *Acacia arabica*, *Terminalia Catappa*, *Euphorbia Tirucalli*, *Phoenix dactylifera*.

2. Mirpur Sakro :

At the time of our visit a great part of the country was still under water. The country is level, rising in a few places to a height of 20—30 ft. Grassland (Savannahs) and fields cover the greater part of the area. Some patches of scrub, chiefly on gravelly soil, make up the rest.

(a) Gravelly soil: *Salvadora oleoides*, (Ill. Nos. 2 and 7) *Tamarix Troupii*, *Capparis decidua*, *Zizyphus nummularia*, *Portulaca oleracea*, *Corchorus antichorus*, *C. tridens*, *C. acutangulus*, *Tribulus terrestris*, *Tephrosia tenuis*, *Trianthema monogyna*, *T. pentandra*, *Boerhaavia diffusa*, *B. verticillata*, *Celosia argentea*, *Euphorbia hypericifolia*, *Eragrostis amabilis*, *Ohloris barbata*, *Eleusine aristata*.

(b) Sandy soil: *Cadaba indica*, *Alhagi camelorum*, *Momordica Charantia*, *Coccinia indica*, *Launaea nudicaulis*, *Vernonia cinerascens*, *Calotropis procera*, *Oxystelma esculentum*, *Pentatropis cynanchoides*, *Leptadenia Spartium*, *Cordia Myaa*, *C. Rothii*, *Heliotropium paniculatum*, *Ipomœa biloba*, *Aerva tomentosa*, *A. pseudo-tomentosa*, *Cenchrus biflorus*, *Sporobolus arabicus*, *Desmostachya cynosuroides*.

(c) Banks of tank and canals: *Tamarix Troupii*, *Bergia ammannioides*, *Sesbania aculeata*, *Prosopis spicigera*, *Ammannia baccifera*, *Eclipta erecta*, *Nerium odorum*, *Cressa cretica*, *Ipomœa aquatica*, *Lippia nodiflora*, *Clerodendron Phlomidis*, *Alternanthera triandra*, *Saccharum spontaneum*, *S. Ravennae*.

(d) In ditches and tanks: *Crinum asiaticum*, *Aponogeton monostachyon*, *Coix Lachryma-Jobi*, *Nymphaea rubra*, *N. stellata*, *Chara sp.*

(e) *Ruderata*: *Sida spinosa*, *Abutilon muticum*, *Trianthema monogyna*, *T. pentandra*, *Solanum xanthocarpum*, *Amarantus viridis*, *A. polygamus*, *Chenopodium murale*, *Euphorbia jodhpurensis*.

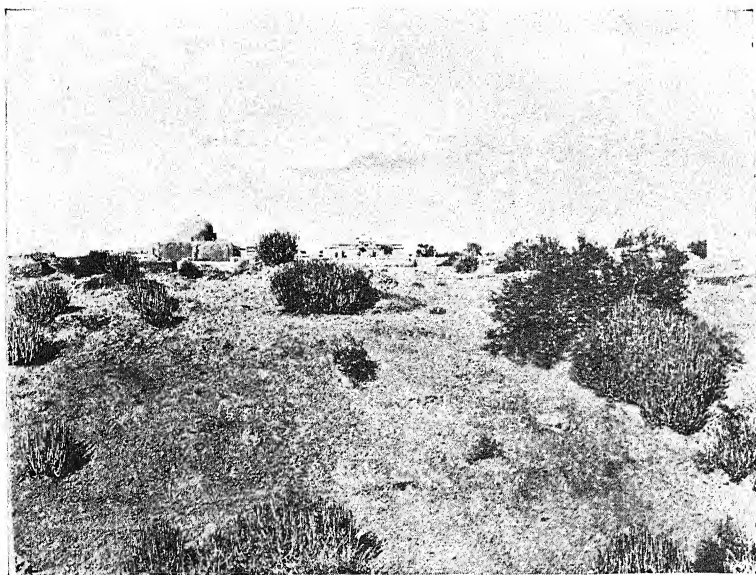
(f) In soil impregnated with salt: *Suaeda fruticosa*, *S. nudiflora*, *S. monoica*, *Aeluropus villosus*.

(g) Cultivated fields: *Digera arvensis*, *Cyperus Haspan*, *C. rotundus*, *Fimbristylis dichotoma*.

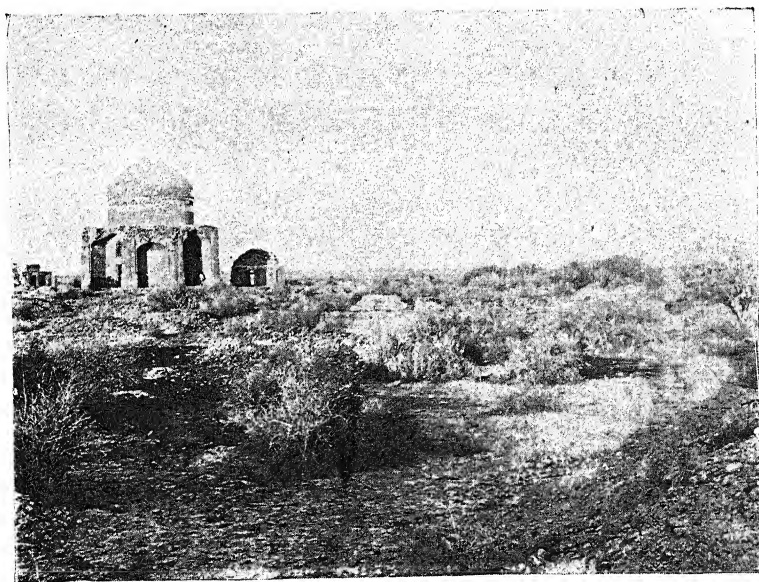
(h) Cultivated: *Eruca sativa*, *Mangifera indica*, *Moringa pterygosperma*, *Phaseolus aconitifolius*, *P. radiatus*, *P. Mungo* var. *Roxburghii*, *Dalbergia Sissoo*, *Pongamia glabra*, *Tamarindus indica*. *Albizia Lebbek*, *Terminalia Catappa*, *Quisqualis indica*, *Psidium Guyava*, *Lawsonia alba*, *Punica granatum*, *Jasminum sambac*, *Lycopersicum esculentum*, *Sesamum indicum*, *Thunbergia fragrans*, *Ricinus communis*, *Morus indica*, *Musa sapientum*, *Phoenix dactylifera*, *Saccharum officinarum*, *Pennisetum typhoideum*, *Oryza sativa*, *Hordeum vulgare*. (Ill. Nos. 5 and 6.)

3. Banks of Bughar Canal: A few miles East of Mirpur Sakro the Bughar Canal flows in a more or less southern direction. The slopes of its bed are built of cut stone and the banks are raised considerably by artificially accumulated sand. Beyond the banks the ground slopes down rapidly to the ordinary level where there are pools of stagnant water, partly the remnants of inundation but at the same time of infiltration from the canal. In this area the following species have been noted: *Tamarix Troupii*, *T. dioica*, *Bergia ammannioides*, *Corchorus tridens*, *Alhagi camelorum*, *Acacia arabica*, *Ammannia baccifera*, *Grangea maderaspatana*, *Gnaphalium pulvinatum*, *Launaea nudicaulis*, *Oxystelma esculentum*, *Leptadenia Spartium*, *Merremia chryseides*, *Solanum xanthocarpum*, *Amarantus viridis*, *A. polygamus*, *Alternanthera triandra*, *Chenopodium murale*, *Euphorbia hypericifolia*, *Phyllanthus reticulatus*, *Echinochloa colona*, *Cynodon dactylon*, *Saccharum spontaneum*, *S. Ravennae*, *Equisetum debile* (not found anywhere else). (Ill. Nos. 8, 9, 39.)

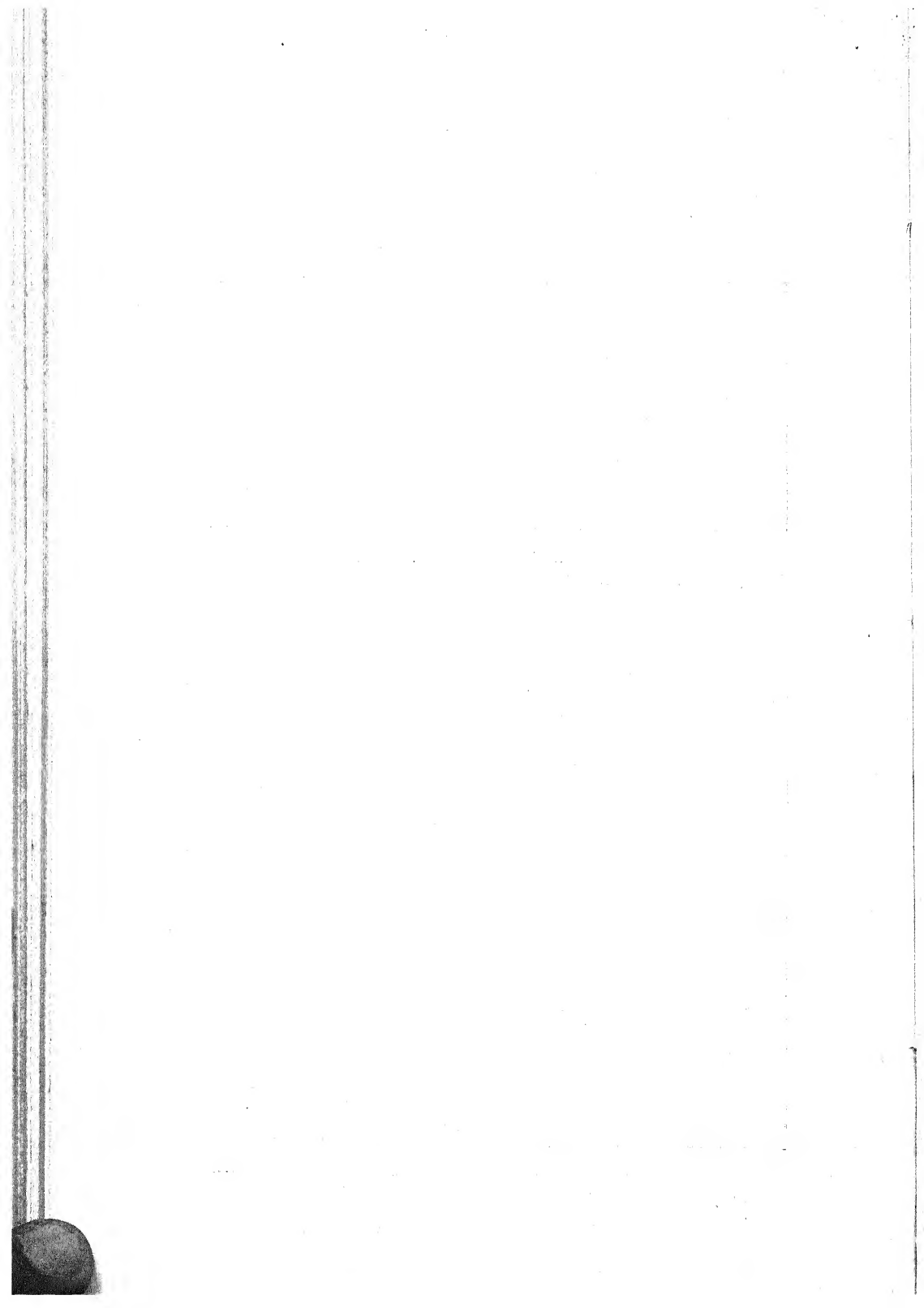
4. Bohara.—This village is reached from Mirpur Sakro by a bad road about 6 miles long going in a S.S.E. direction through marshy country. Along the road the following plants are most prominent, forming sometimes almost pure formations, at other times combining into mixed jungle: *Tamarix Troupii*, *Acacia arabica*, *Cordia Rothii*, *Phyllanthus reticulatus*, *P. Niruri*. Bohara is situated at almost the southernmost point of the Bughar Canal and only a mile or two East of the Seesa Creek, which the canal joins after several windings. The neighbourhood of the creek must be responsible for the rich growth in this place of *Suaeda nudiflora* and *S. monoica*. Otherwise



No. 43. On the Makli Hills near Tatta, an almost pure formation of *Euphorbia caducifolia*.



No. 44. A corner in the Tatta Tombs area: an almost pure formation of *Zizyphus rotundifolia*.



the flora is poor and consists mostly of those species which are common wherever there are human habitations in the Delta: *Abutilon muticum*, *Sida spinosa*, *Corchorus tridens*, *Trianthema monogyna*, *T. pentandra*, *Vernonia cinerea*, *Eclipta erecta*, *Datura fastuosa*, *Chenopodium murale*, *Euphorbia hypericifolia*, *Cyperus rotundus*. Of cultivated plants we mention: *Zizyphus jujuba*, *Cassia fistula*, *Pithecolobium dulce*, *Ficus religiosa*, *Solanum Melongena*.

5. Gholam lies about 12 miles East of Mirpur Sakro on the banks of the Bughar Canal. The soil consists of sand, in some places strongly impregnated with salt. Two miles North-East of Gholam there is a hill-range running from South to North for about 15 miles and consisting of lime-stone. We have examined only that part of it which is nearest to Gholam.

(a) In the sandy soil on which Gholam is built and its neighbourhood we noticed the following: *Maerua arenaria*, *Capparis decidua*, *Ochradenus baccatus*, *Portulaca quadrifida*, *Sida spinosa*, *Abutilon polyandrum*, *A. muticum*, *Zygophyllum simplex*, *Orotalaria juncea*, *Indigofera paucifolia*, *Ammannia baccifera*, *Momordica charantia*, *Melothria maderaspatana*, *Kedrostis rostrata*, *Trianthema pentandra*, *Vernonia cinerascens*, *Pluchea tomentosa*, *Sonchus oleraceus*, *Daemia extensa*, *Oressa cretica*, *Merremia aegyptia*, *Ipomæa eriocarpa*, *Limnophila gratioloides*, *Amarantus viridis*, *A. polygamus*, *Euphorbia hypericifolia*, *Phyllanthus Niruri* (on bank of canal), *Cyperus Haspan*, *C. rotundus*, *Scirpus quinquefarius*, *Cymbopogon Jwarancusa*, *Digitaria sanguinalis*, *Echinochloa colona*, *E. Crus-Galli*, *E. stagnina*, *Setaria verticillata*, *Aristida funiculata*, *Desmostachya cynosuroides* Stapf, *Eleusine aegyptiaca*.

Cultivated in sandy soil: *Brassica nigra*, *B. oleracea*, *Hibiscus esculentus*, *Citrus aurantium*, *Oyamopsis psoralioides*, *Carica papaya*, *Vinca rosea*, *Asclepias curassavica*, *Ipomæa batatas*, *Solanum Melongena*, *Capsicum annum* var., *Euphorbia heterophylla*, *Ricinus communis*, *Musa sapientum*, *Sorghum vulgare*, *Pennisetum typhoideum*.

(b) The low limestone hills East of Gholam are very barren, though from a distance they appear to be covered with fairly dense jungle. There are numerous crippled shrubs and a few dwarf trees growing at considerable distances from each other: *Capparis decidua*, *Commiphora mukul*, *Abutilon fruticosum*, *Gossypium Stocksii*, *Grewia populifolia*, *G. asiatica*, *G. villosa*, *Gymnosporia montana*, *Zizyphus rotundifolia*, *Prosopis spicigera*, *Mimosa hamata*, *Acacia Senegal*, *Periploca* sp., *Oxystelma esculentum*, *Daemia extensa*, *Sarcostemma Stocksii*, *Rivea hypocrateriformis*, *Euphorbia caducifolia*, *Asparagus gharoensis*, *A. dumosus*, *A. deltae*. (Ill. 10, 11, 12, 13, 14, 15, 16, 42).

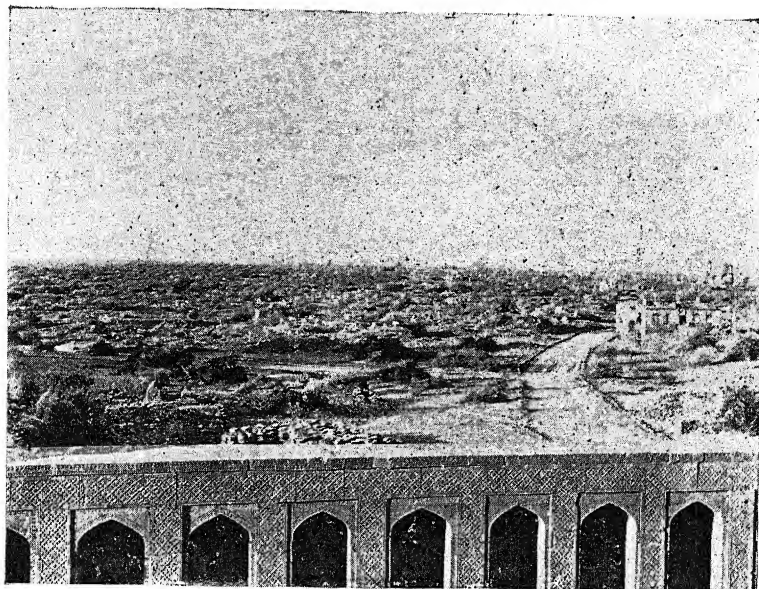
Of herbs and undershrubs we observed the following: *Cleome viscosa*, *Cadaba indica*, *Ochradenus baccatus*, *Tribulus terrestris*, *Zygophyllum simplex*, *Rhynchosia laxiflora*, *Cucumis prophetarum*, *Corallocarpus epigaeus*, *Vernonia cinerea*, *Inula grantioides*, *Pulicaria angustifolia*, *Echinops echinatus*, *Statice Stocksii*, *Heliotropium ophioglossum*, *H. calcareum*, *H. undulatum*, *H. paniculatum*, *Trichodesma indicum* var. *amplexicaule*, *Convolvulus Rotlierianus* var. *tenella*, *Ruellia patula*, *R. prostrata* var. *dejecta*, *Barleria Hochstetteri*, *Pupalia lappacea*, *Heleochloa dura*.

Between Gholam and the lime-stone hills there is a stretch of land densely covered with salt-efflorescence. On it grow *Suaeda fruticosa* and *nudiflora*, *Salsola foetida*.

6. Tatta (24° 46' N. Lat., 67° 59' E. Long.) and its immediate neighbourhood of about 7 miles radius can be divided into two distinct regions: An alluvial portion which consists of a narrow irregular tract E. of Tatta and bordering on the Indus traversed by canals and with a lake near Tatta, and the Makli hills W. of Tatta which are an outcrop in an alluvial plain and consist of nummulitic limestone. These hills rise to a height of 80-150 ft. above sea level. The surface is either solid rock or a thin layer of nodular lumps of hard yellow limestone overlying the undisturbed rocks. The northern half of the Makli hills is a huge cemetery, covered with tombs and mausoleums of considerable age. It is this part of the Makli hills which we examined in detail.

(a) The alluvial plain between Tatta and the Indus consisting of sand and gravel: *Tamarix Troupii*, *T. dioica*, *Cadaba indica*, *Ochradenus baccatus*, *Bergia odorata*, *Triumfetta pentandra*, *Indigofera cordifolia*, *I. anabaptista*, *Taverniera cuneifolia*, *Aeschynomene aspera*, *Acacia arabica* (Ill. No. 17), *Ammannia baccifera*, *Melothria maderaspatana*, *Vernonia cinerea*, *V. cinerascens*, *Blainvillea rhomboidea*, *Volutarella divaricata*, *Dicoma tomentosa*, *Sonchus oleraceus*, *Launaca chondrilloides*, *Pentatropis cynanchoides*, *Daemia extensa*, *Gordia Myra*, *Ipomoea aquatica*, *Physalis minima*, *Bonnaya veronicaefolia*, *Peplidium humifusum*, *Tecomella undulata*, *Leucas urticaefolia*, *Aerva tomentosa*, *Nothosaerva brachiata*, *Alternanthera nodiflora*, *Suaeda fruticosa*, *S. nudiflora*, *Salsola foetida*, *Aristolochia bracteata*, *Phyllanthus Niruri*, *Ephedra foliata*, *Vallisneria spiralis*, *Zanichellia palustris*, 2 species of *Najas*, *Cyperus alopecuroides*, *C. rotundus*, *Fimbristylis ferruginea*, *Eleocharis atropurpurea*, *Scirpus quinquefarius*, *S. maritimus*, *Saccharum Griffithii*, *Paspalidium geminatum*. (Ill. No. 21, 23, 29, 33, 34, 46.)

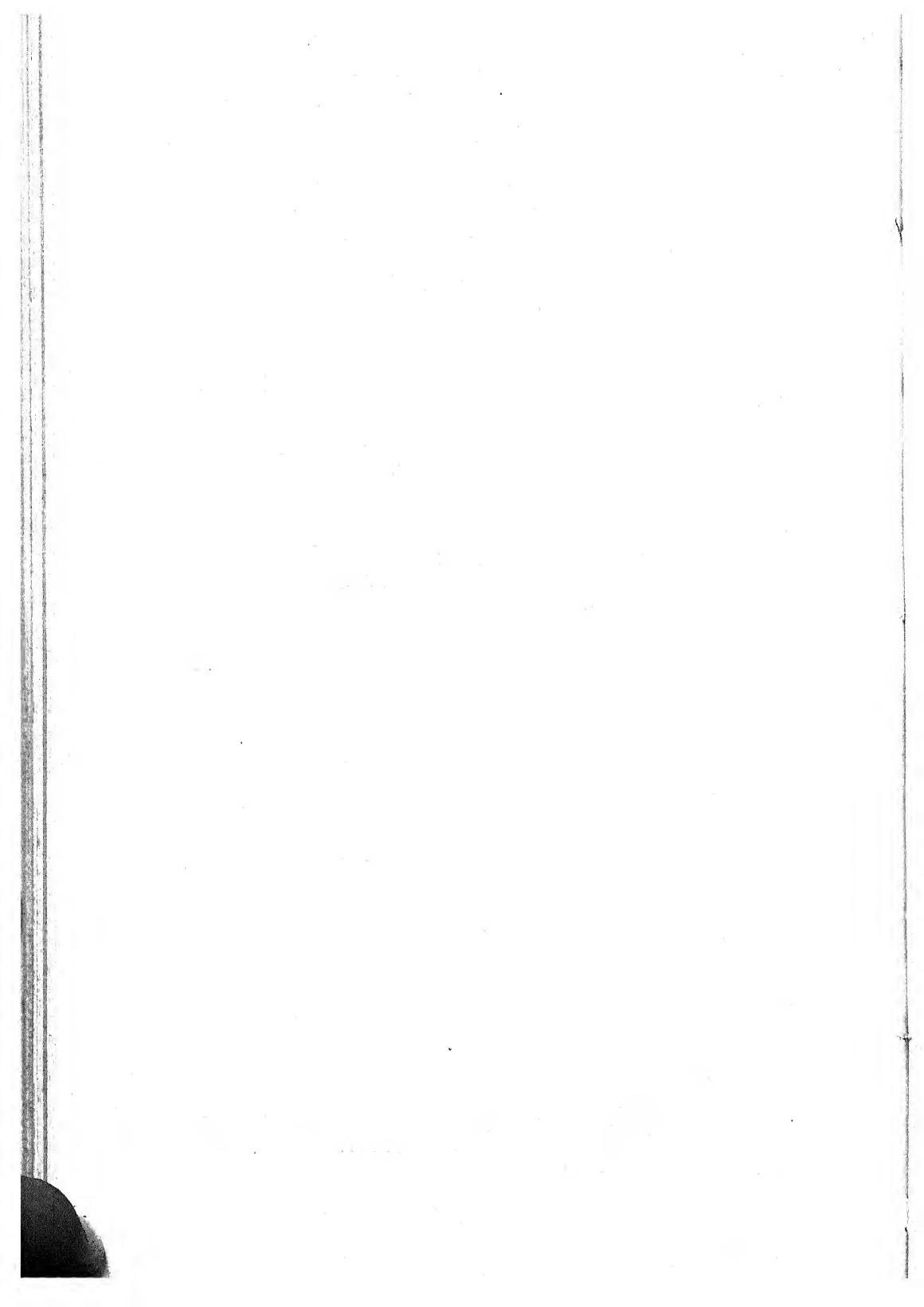
(b) Most species observed on the Makli Hills are of a distinct desert type: *Cocculus pendulus*, *Cleome viscosa*, *Cadaba indica*, *Cap-*



No. 45. The Tombs of Tatta as seen from Nawab Isakhan's Mausoleum: mixed scrub formation of *Capparis decidua*, *Zizyphus rotundifolia*, *Grewia populiifolia*, *Periploca aphylla*, etc.



No. 46. On the banks of the Indus at Bughar: *Tamarix dioica*, *Cyperus rotundus*, *Cressa cretica*.



paris decidua, *Sida grewoides*, *Abutilon muticum*, *A. fruticosum*, *Grewia populifolia*, *G. villosa*, *Corchorus tridens*, *Tribulus terrestris*, *Erodium cicutarium*, *Zizyphus rotundifolia*, *Indigofera anabaptista*, *Tephrosia petrosa*, *Rhynchosia minima* var. *laxiflora*, *Coccinia indica*, *Corallocarpus epigaeus*, *Trianthema pentandra*, *Vernonia cinerascens*, *Pluchea tomentosa*, *P. lanceolata*, *Inula grantioides*, *Pulicaria angustifolia*, *Statice Stocksii*, *Periploca aphylla*, *Daemia extensa*, *Enicostemma littorale*, *Heliotropium ophioglossum*, *H. ovalifolium*, *H. undulatum*, *H. rariflorum*, *Trichodesma indicum* var. *amplexicaule*, *Convolvulus Rotlierianus* var. *tenella*, *C. microphyllus*, *C. rhyncospermus*, *Linaria ramosissima*, *Schweinfurthia sphaerocarpa*, *Lindenbergia abyssinica*, *Lycium barbarum*, *Blepharis sindica*, *Ruellia patula*, *Barleria acanthoides*, *Salvia aegyptiaca*, *Haloxylon recurvum*, *Salsola foetida*, *Euphorbia caducifolia*, *E. granulata*, *E. Clarkeana*, *Andrachne aspera*, *A. sp.*, *Ephedra foliata*, *Asparagus gharoensis*, *A. deltae*, *Commelina albescens*, *Cyperus stoloniferus*, *Dichanthium annulatum*, *Digitaria pennata*, *Eriochloa ramosa*, *Pennisetum cenchroides*, *Cenchrus biflorus*, *Sporobolus arabicus*, *Aristida adscencionis*, *A. funiculata*, *Tragus racemosus*, *Eragrostis ciliaris*, *Chloris barbata*, *Eleusine aegyptiaca*. (Ill. Nos. 22, 27, 30, 31, 32, 41, 43, 44, 45.)

(c) Cultivated: *Moringa pterygosperma*, *Lathyrus sativus*, *Quisqualis indica*, *Casuarina equisetifolia*, *Musa sapientum*, *Saccharum officinarum*.

7. Kullam Kote Lake, a little more than 3 miles South-West of Tatta. It is about 2 miles in diameter and surrounded on three sides by low limestone hills. We had only time to examine the rocky banks and a few spots where, at the mouths of some nalas, fine sediment had been deposited.

(a) On the rocky banks: *Gynandropsis pentaphylla*, *Sida grewoides*, *Abutilon muticum*, *A. fruticosum*, *Senra incana*, *Grewia populifolia*, *Triumfetta rotundifolia*, *Zygophyllum simplex*, *Commiphora Mukul*, *Rhynchosia minima* var. *laxiflora*, *Vernonia cinerascens*, *Pentatropis cynanchoides*, *Cordia Rothii*, *Heliotropium paniculatum*, *Solanum albicaule*, *Tecomella undulata*, *Blepharis sindica*, *Ruellia patula*, *Barleria Prionitis*, *Justicia heterocarpa*, *Leucas urticaefolia*, *Euphorbia caducifolia*, *Dichanthium annulatum*, *Digitaria pennata*, *Eriochloa ramosa*, *Pennisetum cenchroides*, *Aristida adscencionis*, *Diplachne fusca*. (Ill. Nos. 25, 26.)

(b) On sediment: *Portulaca oleracea*, *P. quadrifida*, *Corchorus antichorus*, *C. tridens*, *Indigofera cordifolia*, *I. anabaptista*, *Trianthema pentandra*, *Vernonia cinerea*, *Launaea nudicaulis*, *Cressa cretica*, *Clerodendron Phlomidis*, *Amarantus polygamus*, *Suaeda monoica*,

Haloxylon recurvum, *Salsola foetida*, *Phyllanthus Niruri*, *Cyperus alopecuroides*, *C. rotundus*, *Phragmites karka*, *Panicum*. (Ill. No. 24.)

8. Banks of Indus (Ill. No. 18, 19, 35, 36): All along the Indus, almost right down to its mouth there are vast forests of *Tamarix dioica*, *T. Troupii*, *T. articulata*, *Acacia arabica*, *A. Farnesiana*, *Populus euphratica*, *Prosopis spicigera*. Pure or almost pure formations of *Tamarix dioica* or *T. Troupii* are very common. Generally they are so dense that it is almost impossible to cross them, quite apart from the obstacle offered by the clay or sandy clay in which they grow. As pointed out above new alluvium is deposited by the Indus every year, covering a belt along the river several hundred meters broad and reaching even miles in certain places. The alluvium is being submerged at the time of inundation and new deposits are added at the same time. As soon as the alluvium rises above the surface of the water, *Tamarix* seeds begin to germinate in great numbers. The growth is so dense that, seen from the boat, it can easily be mistaken for a meadow or a wheat-field in its earliest stage. The *Tamarix* is often mixed with *Saccharum spontaneum* or *S. Ravennae* which, however, are killed out by the growing *Tamarix*. But it also happens that the *Saccharum* survives in pure formations offering a beautiful sight at the time of flowering. In consequence of the annual floods the land continues rising and ere long the *Tamarix* partially disappears giving place to *Populus euphratica* and *Acacia arabica* or *A. Farnesiana*, or both. (Ill. Nos. 37, 38). As the land rises still more it is not affected by annual floods, but is subject only to abnormal inundations. It is at this time that *Prosopis spicigera* takes possession of the ground, though not exclusively. It is not easy to kill the *Tamarix* and we find an undergrowth of it far inland, even in places where, on account of the dryness of the soil, *Capparis aphylla* makes its appearance. The soil has a great influence on the development of *Tamarix Troupii*. Stiff clay or pure sand produces a stunted plant, but good alluvial loam with an adequate water-content develops the plant into a small tree.

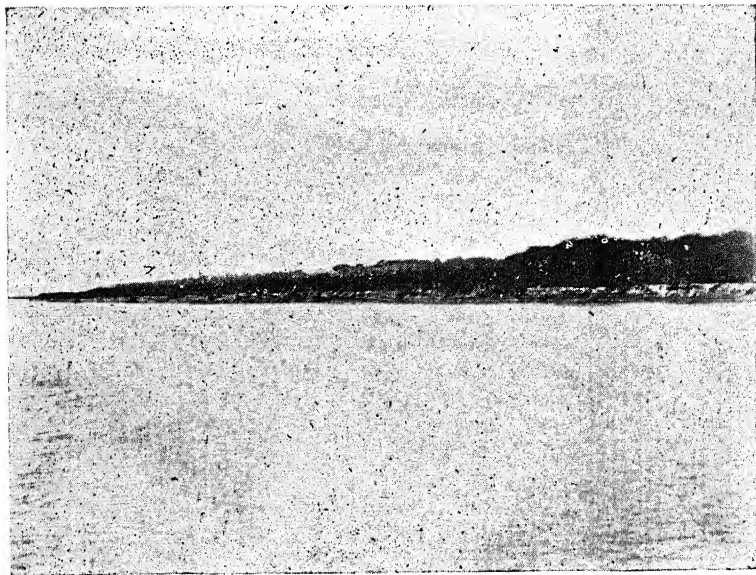
It is interesting to note that on the whole *Tamarix dioica* shows a predilection for higher elevations impregnated with salt, which are rarely or never affected by floods.

Tamarix articulata is the least common species in the Delta. It is usually found far away from the Indus, associated with *Salvadora oleoides*, *Capparis decidua* and often with *Prosopis spicigera*. Loam, but also stiff clay and sand, are its favourite habitats. Saline soils are not despised as long as surface irrigation is provided, but it will not grow on soil which is heavily impregnated with salts.

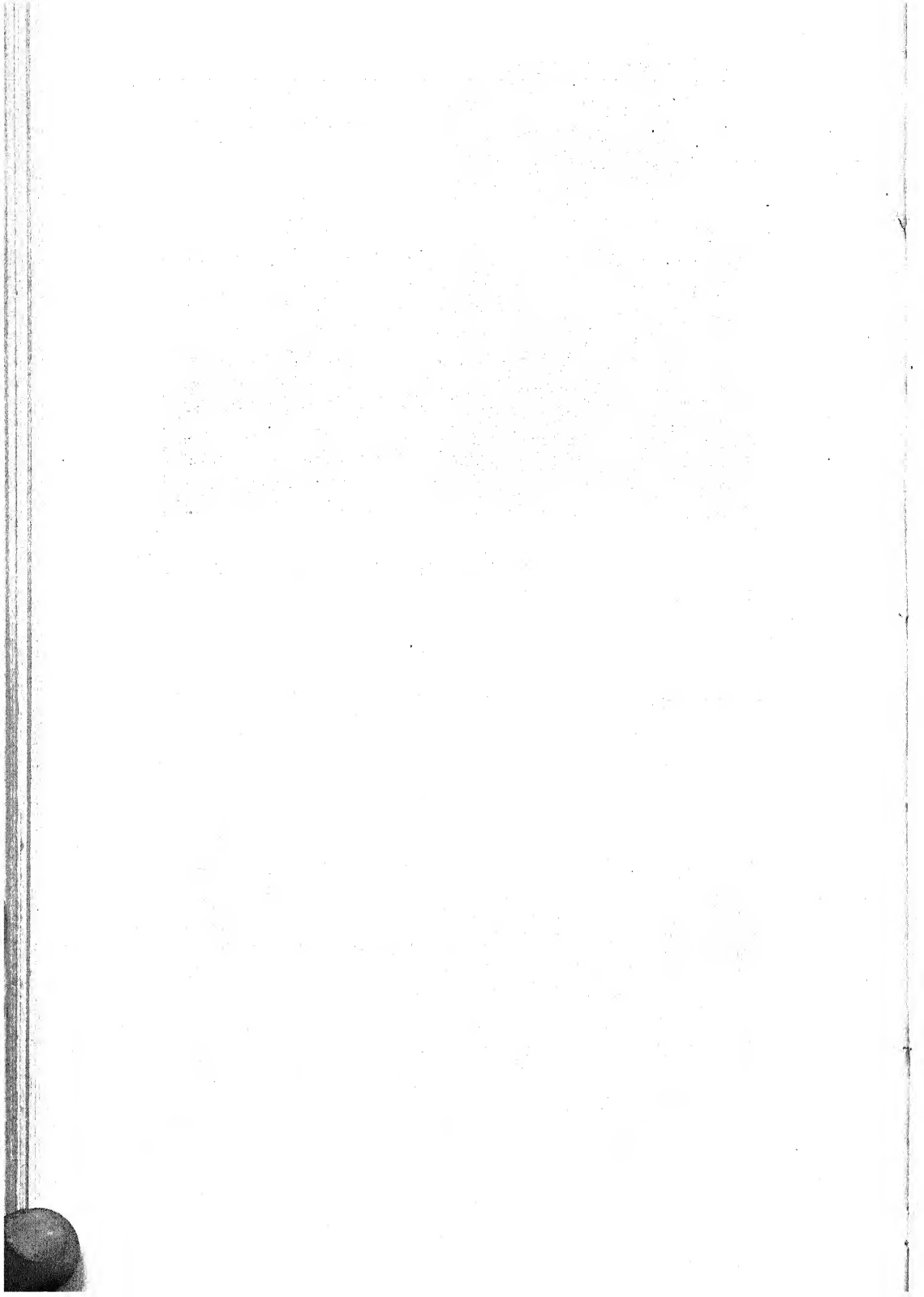
The Babul forests, whether on the banks of the Indus or several

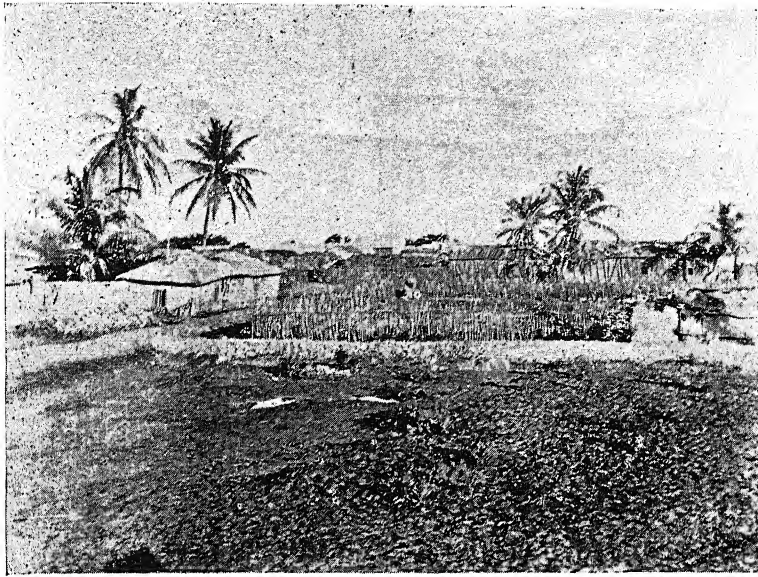


No. 47. Ketī Bandar with *Phoenix dactylifera*, *Oryza coarctata* and *Cyperus tegetum*.

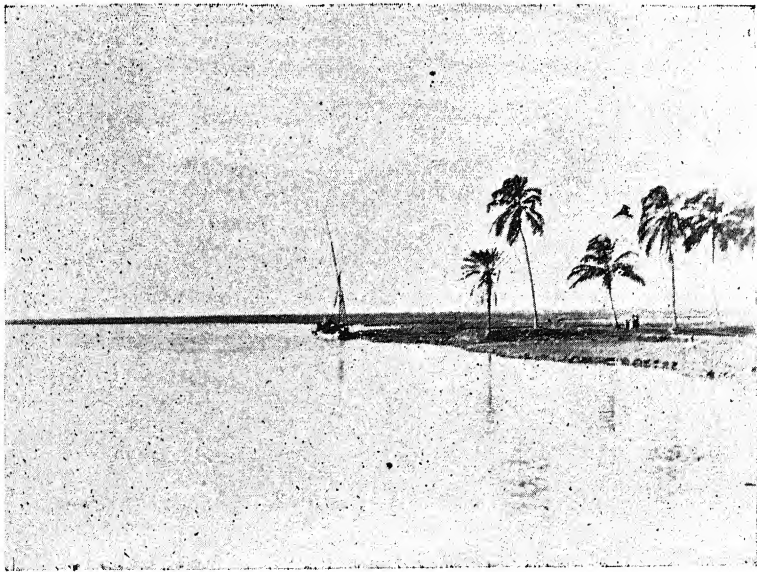


No. 48. On the right bank of the Indus. To the left, pure formation of *Saccharum Ravennae*; to the right, *Acacia arabica*.





No. 49. Ketibandar with *Cocos nucifera* Linn.; in the background, *Tamarix Troupii* and *Thespesia populnea*.



No. 50. Ketibandar on the banks of the Hajamro, with *Cocos nucifera* Linn.

miles away from the river, contain occasionally other species, some of which have been introduced: *Cordia Rothii*, *C. Myra*, *Ficus bengalensis*, *Azadirachta indica*, *Zizyphus Jujuba*, *Albizia Lebbek*, *Parkinsonia aculeata*, *Tamarindus indica*, *Acacia Farnesiana*.

In many places along the Indus there are vast areas covered with pure formations of *Typha elephantina* or *Saccharum spontaneum* or *S. Ravennae*. (Ill. No. 48).

Not far from the coast extensive mudbanks can be seen covered with *Oryza coarctata*, an excellent mud and sand-binding plant. The plants we saw in October were flowering and fruiting though they had not reached more than 5-8 cm. in height. (Ill. No. 20.)

9. Keti Bandar (24° 8' N. Lat., 67° 30' E. Long.) rose at the time of our visit only about 30 cm. above the water-level. As far as the eye can see there are only silt-banks and water, with here and there a tree or scanty herbs. We observed the following species: *Tamarix Trupii*, *Thespesia populnea*, *Ipomœa aquatica*, *Peplidium humifusum*, *Tecomella undulata*, *Phyllanthus distichus*, *Cocos nucifera*, *Phoenix dactylifera*, *Pandanus tectorius*, *Cyperus tegetum*, *Echinochloa Crus-Galli*, *Phragmites karka*, *Oryza coarctata*. (Ill. Nos. 40, 47, 49, 50.)

The land near the Hajamro river is one extensive swamp, reaching about 5 miles up the river, with a thin covering of a species of coarse spiny grass (*Aeluropus villosus*?) mixed with rushes. Above this swamp low mangrove-bushes begin to grow and cultivation can be observed. The mangrove jungles which are common not only in this place but all along the coast from the Khorī Creek right up to Karachi wherever there is a creek or the mouth of a river, but always some distance inland, consist of the following species: *Aegiceras majus*, *Rhizophora mucronata*, *R. conjugata*, *Ceriops Candolleana*, *C. Roxburghiana*, *Bruguiera gymnorhiza*, *Sonneratia acida*, *Avicennia officinalis*. Our material is not sufficient to enable us to make any definite statement as to the exact distribution of the single species. In the same area, but not in the same habitats we noticed the following plants: *Scaevola frutescens*, *S. Plumierii*, *Arthrocnemum indicum*, *Suaeda fruticosa*, *S. nudiflora*.

For an account of the cultivated plants see: G. R. Ambekar, the Crops of Sind: Their Geography and Statistics. Bull. 150, Dept. Agric. Bombay, 1928.

(To be continued.)

Presidential Address delivered before
the Annual Meeting of the Indian Botanical Society
at Calcutta, January, 1928.

MYRMECOSYMBIOSIS IN THE INDO-MALAYAN
FLORA

BY

E. BLATTER, S. J., Ph.D., F. L. S.

LADIES AND GENTLEMEN,

In 1886 F. Delpino estimated the number of 'myrmecophilous' plants at 2,904 species distributed over 273 genera. A rich and varied literature has, in the meantime, dealt with the relations between ants and plants observed in the temperate regions, but quite especially in the tropics of both hemispheres. It is an interesting subject, and once the attention of biologists was directed to it, men were not wanting who looked for special adaptations in a plant wherever an ant was found associated with it in some way or other. Detailed observations were often defective, sometimes entirely absent, but this circumstance only gave more room to imagination and wild speculation without solid foundation. We have seen the same mental process in many other domains of biology. And the results were the same: A small number of well observed facts and a great number of premature conclusions, an endless string of hypothetical premises and finally a self-confident positive assertion which is in no way contained in the premises.

I wish to put before you the material that is at our disposal regarding the myrmecophytes of the Indo-Malayan flora. It is clear that we cannot deal with every case that has been mentioned by various writers. But, in order to be quite fair in every respect I wish to mention those instances from which the chief and best arguments in favour of myrmecosymbiosis have been derived.

I have adopted the name myrmecophytes in preference to the older expression myrmecophilous plants. In this I am only following Warming. He has rightly pointed out that myrmecophily is a term not very well chosen, because it already includes a hypothesis to the effect that the plants have a certain biological interest in being visited by ants, in the same way as we speak of xerophilous plants because they show a predilection for dry habitats. Myrmecophyte is a more general term and can be translated with 'ant-plant,' signifying any

plant that has some definite relation to ants. As myrmecosymbiotic plants we can consider all those species which in some way or other exhibit hereditary anatomical or morphological characters.

We shall treat only of those instances which may be real cases of myrmecosymbiosis or have been considered as such. The final question will be whether true myrmecosymbiosis has been observed in the Indo-Malayan vegetation. Instead of adducing all the facts first and then discussing their meaning, we shall take fact after fact and try to explain each one independently. You will agree with me that no accumulation of unconvincing single facts can lead to a convincing conclusion.

Beccari has figured and described a great number of plants from the Malay Archipelago which are inhabited by numerous ants. Special structures and organizations in the plants were interpreted as adaptations to symbiotic life, without, however, giving satisfactory proofs. *Olerodendron fistulosum*, Becc., of Borneo, like *Olerodendron myrmecophilum* of Malacca have branches with hollow internodal chambers which are largely inhabited by ants. At the upper end of the internodes below the leaves there are two layers of tissue composed of thin-walled parenchyma. These layers offer little resistance to ants trying to pierce them and as a matter of fact, it is here that ants always force their entrance into the hollow chambers. It is true that ants find protection in the hollows of the branches, but in what way the plant benefits by their presence has not been stated. Special food-bodies have not been noted in *C. fistulosum*, but the lower surface of the opposite leaves of this shrub is covered with numerous nectaries.

In the Malay Peninsula, Sumatra, Java and Borneo there is a tree reaching over 10 m. in height, *Macaranga triloba*, Muell. (Euphorbiaceae, figured in Wight Ic. t. 1949, fig. 5 under *Pachystemon trilobus*, Bl.). It shows peculiar bodies which resemble those of Mueller observed in *Cecropia adenopus*, Mart. of tropical America. Here, too, we find hollow internodes frequented by large numbers of ants. The leaf-buds are surrounded by scales which bend back and downwards after the opening of the buds. As these scales are pressed to the branches a kind of gallery is formed in this place all round the branch. On the lower surface of those scales i.e., inside the gallery, there appear small white bodies which are eaten by the ants inhabiting the galleries. Ridley considers this to be a typical case of myrmecosymbiosis, but does not say anything about the advantages derived by the plant from the presence of the ants. In all probability these bodies, like those of Mueller, belong to a group of glandular excrecences which are also found elsewhere. It is well known that

many Ampelidaceae e.g. *Leca*, *Vitis*, *Ampelopsis*, possess similar white bodies on their petioles, young shoots, and nerves on the lower surface of their leaves. They are called pearl-glands and are specially well developed even on the older branches and leaves of *Vitis hederacea*, Ehrh. But all these plants have never been noted to be frequented by ants. Raciborski who watched winding species of *Gnetum* in the Botanic Garden of Buitenzorg did not observe that those glands were eaten by ants under normal conditions. Only when he brought the ants in contact with the glands the latter were devoured within a short time. These species of *Gnetum* develop the pearl-glands only on the long winding shoots, and not on the short assimilating branches. Arising usually after rain or during the night they are very caducous and shrivel up very soon. Their diameter is about 0.5 mm. and they contain starch in the beginning which, however, soon disappears. Similar glands have been observed in a species of *Pterospermum* common in Java. On the petioles of the distichously arranged leaves there are two kinds of stipules; one is awl-shaped, caducous and directed upwards, the other has the shape of a small bell, directed downwards. The inner wall of this bell is covered with a felt of hairs which are mixed with numerous small glands about 0.3 mm. in diameter. These contain considerable quantities of fat, albumen and polysaccharides. A kind of black ant inhabits these bells and feeds on the glands. Though the glands are seen only on the youngest leaves, the ants are found all over the tree. There is no doubt that ants are fond of those glands. But this does not prove that the glands were destined for the ants from the beginning. There are many plants producing glands rich in food-stuffs (many *Vitaceae*, *Piperaceae*, *Moraceae*, *Melastomaceae*, *Urticaceae*, *Gnetaceae*), but are we justified in calling them myrmecosymbionts? It is true that we have not yet understood the significance of those pearl-glands, that we do not know what part they play in the metabolism of the plant. But this ignorance cannot induce us, without further evidence, to state that they were produced by the plant in order to attract ants. It is also true that by the production and subsequent loss of the glands the plant loses a not inconsiderable amount of material valuable to the plant and all this apparently without gaining by it in any way. The mere fact that we are unable to give a satisfactory explanation does not justify us to draw a conclusion for which we have no other evidence except the fact that in many cases ants are associated with those bodies. It is quite possible that those 'food-bodies' have been present for ages and that the ants only in course of time discovered this welcome source of food.

Many other so-called 'myrmecophilous' plants cannot be considered as such, even if we take the word in its wider sense. We take

only a few of the more striking instances: "A peculiar character of *Korthalsia*," says Beccari, "is the great development of the appendage at the mouth of the leaf-sheaths (the ochrea) which at times is transformed into a swollen and entirely closed ant-harbours organ or nidus, of a constant form for every species (*K. scaphigera*, *scaphigeroides*, *echinometra*, *horrida*, *Cheb*, *angustifolia*, *Scortechinii*, *furcata*). In *K. robusta* and *K. macrocarpa*, the ochreae do not form an entirely closed dwelling for ants, but take the shape of large cornets embracing the base of the sheaths immediately above them, and at times attaining the extraordinary length of 30 to 40 cm. In most species, however, the ochreae are cylindrical, closely sheathing, and often partially disintegrated into a fibrous net. The form and peculiarities of the ochrea afford often the best characters by which to distinguish the species, even if flowers and fruits be wanting. The nature, origin, and function of the ant-harbours organs, not only in *Korthalsia*, but in numerous myrmecophilous plants, and most of all, in *Myrmecodia* and *Hydnophytum*, have been much discussed: with regard to this subject I retain my old opinion that such organs are now hereditary, but that they owed their origin to the effects of the stimulus exerted by ants on certain organs of the plants, of which tissues were capable of a reactive power during the remote period of the plasmatation epoch, when heredity had not yet acquired its actual conservative power."

With regard to *Korthalsia* Ridley has pointed out that its species are not always inhabited by ants. The same objection applies to *Dischidia Rafflesiana*, Wall., a liana growing from Tenasserim to Malacca and very common in the Malay Archipelago, which develops peculiar tube-like leaves which gather water and detritus to be taken up by the plant by its adventitious roots. There are no Ant-acacias in the Indo-Malayan flora, but Ridley observed in the Botanic Garden of Singapore how an indigenous ant took possession of an *Acacia spadici-gera*, Cham. and Schlecht., a species introduced from Jamaica, quite in the same way as other species of ants do it in America. Schimper claimed the hollow branches of *Ficus inaequalis* as dwellings of ants, but since then they have been recognized as pathological formations. Schumann and Schimper counted amongst the 'myrmecophilous' plants, *Humboldtia laurifolia*, Vahl, indigenous in Malabar and Ceylon, but Escherich who observed the plant in Ceylon was not able to notice any more intimate relations between ant and plant. We find in *Humboldtia* the internodes of the branchlets conspicuously swollen and hollow inside. The opening to the hollows does not arise spontaneously, but the enclosing wall has to be perforated by the ants. In addition the ants are perfectly harmless and cannot, therefore, serve

the plant as protectors. But what is more, instead of being useful to the plant the ants do it considerable harm by attracting wood-peckers which wound the branches, and also by rearing plant-lice.

We mentioned above *Myrmecodia* and *Hydnophytum*. Both are epiphytic shrubs belonging to the family *Rubiaceæ*. *Myrmecodia tuberosa*, Blume, is at home in the Malay Archipelago and *Hydnophytum montanum*, Blume, has been found in the South Andaman Islands, Malay Peninsula and Archipelago. They grow in the upper regions of the dense crowns of trees, e. g. of *Durio zibethinus*, Murr. and *Artocarpus integrifolia*, Linn. f. Both are distinguished by a large tuber arising from the hypocotyl, often reaching in *Myrmecodia* 75 cm. in diameter, and 30 cm. in *Hydnophytum*. Labyrinthic hollows make up the interior of the tubers. The walls of the labyrinth are of two kinds: One part is smooth, light-brown, the other blackish and covered with small warts. According to Miede the ants (*Iridomyrex*) deposit their pupae only in the smooth chambers, whilst the excrements are secreted on the warty walls. On the latter there grow fungi belonging to the genera *Cladosporium* and *Cladotrichum*.

Rumphius (Herbarium amboinense, 1750) thought those tubers were zoophytes, imagining that the ants worked the branches into a nest from which those tubers emerged. Beccari considered them as a definite proof in favour of his hypothesis. He was of opinion that the tubers as well as the internal labyrinth were due to the activity of the ants. Treub was the first to show that the galleries of the tubers develop even without the help of ants, and that the ants are perfectly useless for the growth of the plant and even for the ripening of the fruit. The same writer considered the warts on the walls of the chambers to be lenticels and, consequently, for him the labyrinth was only a system of aeration for the benefit of the plant. But here Treub found his opponents. Goebel speaks of the tuber as of a water-reservoir and Karsten calls the warts organs of absorption, and Rettig takes the galleries for isolators which are meant to protect the tubers against over-heating, considering that they grow high up in the trees. Miede, relying to some extent on experimental investigations came to the conclusion that the warts are organs of absorption, which take up the water held back in the galleries by capillary action and absorb, at the same time, the nitrogenous substances derived from the excrements of the ants and dissolved in the water. We could, therefore, say with some confidence that the ants by depositing their excrements in the galleries are a distinct help in the manuring of the plant. In spite of all this the fact remains that even in these famous myrmecophytes there are no special organizations which could be interpreted as original adaptations to visiting ants.

Whether the ants in this case can offer some protection to the plants is, of course, not decided, but it does not seem to be likely if we consider the harmlessness of the ants in question.

We have still to say a word regarding another class of so-called myrmecophilous plants *viz.* the numerous species with extra-floral nectaries which are so common all over our region. Nectaries are glands of various structure which occur either in the flowers or outside the flowers on different parts of the plant-body. The former are called floral, the latter extra-floral nectaries. The former are rightly considered as special adaptations which favour insect-visits. Footing on the accepted theory of the relations between honey-seeking insects and the plant thus securing cross-fertilization, the temptation was strong to look for similar relations between ants and extra-floral nectaries. The ants are said to drink the nectar of the glands and, getting used to the plant, to form a kind of army defending the plant against its numerous enemies. This view gave an apparently satisfactory explanation of the function of extra-floral nectaries. There are a number of circumstances which speak in favour of that opinion: The plant is in need of protection from the attacks of caterpillars and beetles and other insects, the extra-floral nectaries on the young parts of the plants are well-adapted to attract the ants to those organs which more than others require special protection, and finally the fact that those extra-floral nectaries are more common in tropical countries where ants play a more important part than in other countries. Further, the fact cannot be denied that innumerable cases have been observed where ants frequent those glands. But here again the same question arises: In what way do the plants benefit by the presence of ants? Nieuwenhuis von Uexküll-Güldenbandt working on the rich material in the Botanic Garden of Buitenzorg has tried to elucidate this point. Her conclusions go distinctly against symbiotic conditions. Bees, bumblebees and wasps are not prevented by ants from boring holes into the flowers. Caterpillars, beetles, bugs and larvae of various kinds are not only not expelled by ants, but the latter are attacked by them. Many cases have been observed where other insects drink the nectar from the same cup together with the ants. It is, therefore, very doubtful whether plants with extra-floral nectaries suffer less from harmful insects than others which are devoid of glands. On the contrary, in many cases the presence of ants turns out to be fatal to the plant on account of the numerous plant-lice nursed by the ants. In addition, observations are not wanting where ants have eaten the nectaries and damaged the leaves and, finally, a number of harmful insects are attracted by the same nectaries. Another fact

should not be overlooked *viz.* that very often there are no nectaries on the young parts of the plant where they would be most needed, whilst they develop freely on older organs.

I have given the more important cases of 'myrmecophily' in the Indo-Malayan region. Have we seen one true case of myrmecosymbiosis? The answer depends on whether two points are verified in any particular instance: First, the plant has to derive a distinct advantage from the presence of the ants, and the ants must be in a position to offer an advantage. Secondly, the plant must exhibit structures which can only be interpreted as adaptations to ant-visits.

As to the first point there are very few cases in which ants seem to be of some probable advantage to the plant. Most ants cannot protect the plants against enemies, because they are not carnivorous. This applies especially to the harmless forms which drink the nectar. As regards the second point we have no proof whatever. Cavities are a common occurrence in plants. The hollow internodes generally find a sufficient explanation in the mechanical architectonic principles on which the respective plant is built. The tubers of *Myrmecodia* and *Hydnophytum* have been discussed before. In most cases we must assume that the ants utilise all those structures in the same way as they make use of any hole they may find on their rambles. It is well known to every observer how quickly ants adapt themselves in tropical countries to any condition, which was absolutely unknown to them before. The botanist who sees an apparent symbiosis between ants and plant for the first time is only too easily tempted to find the initiative for that adaptation in the plant instead of in the ant. It is also very likely that insufficient knowledge of the habits of the various ants is responsible for many mistakes made in such observations.

I put in the beginning the question whether true myrmecosymbiosis has been observed in the Indo-Malayan vegetation. After what I have explained I am afraid I have to answer in the negative. I do not wish to say that myrmecosymbiosis does not exist in Indo-Malaya, but I find it impossible to admit that it has been proved to evidence in any particular case. It is always sad to give up an idea one has cherished for a long time, especially if that idea has been put into the world by able men and if it has been supported by enthusiastic workers during generations. We live in a time when every field of botanical science is ploughed by a greater number of men than was the case even 50 years ago, and many more have nowadays an opportunity of examining things and testing facts on the spot, instead of speculating on dry herbarium specimens and trying to harmonize a variety of reports brought home by travellers sometimes little qualified for accurate observations.

It is, therefore, to be expected that deeper knowledge and more careful observations will correct many wrong notions which have crept into plant-biology in course of time. We all have to fight against the tendency of premature generalisations. We are never satisfied with the mere statement of facts, we all want to explain and combine facts in order to draw conclusions. It is a happy craving of our mental faculties, but also a dangerous one and leading to error if not every link in the chain of our argumentation represents a well-ascertained and unimpeachable fact.

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